BRITISH ASSOCIATION
FOR THE ADVANCEMENT OF SCIENCE

REPORT

OF THE

ANNUAL MEETING, 1933

(103RD YEAR)

LEICESTER

SEPTEMBER 6–13

LONDON
OFFICE OF THE BRITISH ASSOCIATION
BURLINGTON HOUSE, LONDON, W. 1

1933

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PATRON.

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PRESIDENT, 1933.

Sir FREDERICK GOWLAND HOPKINS, D.Sc., Sc.D., LL.D., Pres.R.S.

PRESIDENT, 1934.

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The LORD BISHOP OF LEICESTER (The Rt. Rev. C. C. B. BARDSLEY, D.D.).

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Alderman Sir JONATHAN NORTH, D.L., J.P.

The Rev. BERNARD UFFEN, A.T.S.

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A Department of Industrial Co-operation—*Chairman*, Dr. J. A. Bowie ; *Secretary*, R. J. Mackay—arranged a special programme in connection with this and other Sections.

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President.—Dr. R. E. Mortimer Wheeler.
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TABLE OF

Date of Meeting	Where held	Presidents	Old Life Members	New Life Members
1831, Sept. 27	York	Viscount Milton, D.C.L., F.R.S.	—	—
1832, June 19	Oxford	The Rev. W. Buckland, F.R.S.	—	—
1833, June 25	Cambridge	The Rev. A. Sedgwick, F.R.S.	—	—
1834, Sept. 8	Edinburgh	Sir T. M. Brisbane, D.C.L., F.R.S.	—	—
1835, Aug. 10	Dublin	The Rev. Provost Lloyd, LL.D., F.R.S.	—	—
1836, Aug. 22	Bristol	The Marquis of Lansdowne, F.R.S.	—	—
1837, Sept. 11	Liverpool	The Earl of Burlington, F.R.S.	—	—
1838, Aug. 10	Newcastle-on-Tyne	The Duke of Northumberland, F.R.S.	—	—
1839, Aug. 26	Birmingham	The Rev. W. Vernon Harcourt, F.R.S.	—	—
1840, Sept. 17	Glasgow	The Marquis of Breadalbane, F.R.S.	—	—
1841, July 20	Plymouth	The Rev. W. Whewell, F.R.S.	169	65
1842, June 23	Manchester	The Lord Francis Egerton, F.G.S.	303	169
1843, Aug. 17	Cork	The Earl of Rosse, F.R.S.	109	28
1844, Sept. 26	York	The Rev. G. Peacock, D.D., F.R.S.	226	150
1845, June 19	Cambridge	Sir John F. W. Herschel, Bart., F.R.S.	313	36
1846, Sept. 10	Southampton	Sir Roderick I. Murchison, Bart., F.R.S.	241	10
1847, June 23	Oxford	Sir Robert H. Inglis, Bart., F.R.S.	314	18
1848, Aug. 9	Swansea	The Marquis of Northampton, Pres. R.S.	149	3
1849, Sept. 12	Birmingham	The Rev. T. R. Robinson, D.D., F.R.S.	227	12
1850, July 21	Edinburgh	Sir David Brewster, K.H., F.R.S.	235	9
1851, July 2	Ipswich	G. B. Airy, Astronomer Royal, F.R.S.	172	8
1852, Sept. 1	Belfast	Lieut.-General Sabine, F.R.S.	164	10
1853, Sept. 3	Hull	William Hopkins, F.R.S.	141	13
1854, Sept. 20	Liverpool	The Earl of Harrowby, F.R.S.	238	23
1855, Sept. 12	Glasgow	The Duke of Argyll, F.R.S.	194	33
1856, Aug. 6	Cheltenham	Prof. C. G. B. Daubeney, M.D., F.R.S.	182	14
1857, Aug. 26	Dublin	The Rev. H. Lloyd, D.D., F.R.S.	236	15
1858, Sept. 22	Leeds	Richard Owen, M.D., D.C.L., F.R.S.	222	42
1859, Sept. 14	Aberdeen	H.R.H. The Prince Consort	184	27
1860, June 27	Oxford	The Lord Wrottesley, M.A., F.R.S.	286	21
1861, Sept. 4	Manchester	William Fairbairn, LL.D., F.R.S.	321	113
1862, Oct. 1	Cambridge	The Rev. Professor Willis, M.A., F.R.S.	239	15
1863, Aug. 26	Newcastle-on-Tyne	Sir William G. Armstrong, C.B., F.R.S.	203	36
1864, Sept. 13	Bath	Sir Charles Lyell, Bart., M.A., F.R.S.	287	40
1865, Sept. 6	Birmingham	Prof. J. Phillips, M.A., LL.D., F.R.S.	292	44
1866, Aug. 22	Nottingham	William R. Grove, Q.C., F.R.S.	207	31
1867, Sept. 4	Dundee	The Duke of Buccleuch, K.C.B., F.R.S.	167	25
1868, Aug. 19	Norwich	Dr. Joseph D. Hooker, F.R.S.	196	18
1869, Aug. 18	Exeter	Prof. G. G. Stokes, D.C.L., F.R.S.	204	21
1870, Sept. 14	Liverpool	Prof. T. H. Huxley, LL.D., F.R.S.	314	39
1871, Aug. 2	Edinburgh	Prof. Sir W. Thomson, LL.D., F.R.S.	246	28
1872, Aug. 14	Brighton	Dr. W. B. Carpenter, F.R.S.	245	36
1873, Sept. 17	Bradford	Prof. A. W. Williamson, F.R.S.	212	27
1874, Aug. 19	Belfast	Prof. J. Tyndall, LL.D., F.R.S.	162	13
1875, Aug. 25	Bristol	Sir John Hawkshaw, F.R.S.	239	36
1876, Sept. 6	Glasgow	Prof. T. Andrews, M.D., F.R.S.	221	35
1877, Aug. 15	Plymouth	Prof. A. Thomson, M.D., F.R.S.	173	19
1878, Aug. 14	Dublin	W. Spottiswoode, M.A., F.R.S.	201	18
1879, Aug. 20	Sheffield	Prof. G. J. Allman, M.D., F.R.S.	184	16
1880, Aug. 25	Swansea	A. C. Ramsay, LL.D., F.R.S.	144	11
1881, Aug. 31	York	Sir John Lubbock, Bart., F.R.S.	272	28
1882, Aug. 23	Southampton	Dr. C. W. Siemens, F.R.S.	178	17
1883, Sept. 19	Southport	Prof. A. Cayley, D.C.L., F.R.S.	203	60
1884, Aug. 27	Montreal	Prof. Lord Rayleigh, F.R.S.	235	20
1885, Sept. 9	Aberdeen	Sir Lyon Playfair, K.C.B., F.R.S.	225	18
1886, Sept. 1	Birmingham	Sir J. W. Dawson, C.M.G., F.R.S.	314	25
1887, Aug. 31	Manchester	Sir H. E. Roscoe, D.C.L., F.R.S.	428	86
1888, Sept. 5	Bath	Sir F. J. Bramwell, F.R.S.	266	36
1889, Sept. 11	Newcastle-on-Tyne	Prof. W. H. Flower, C.B., F.R.S.	277	20
1890, Sept. 3	Leeds	Sir F. A. Abel, C.B., F.R.S.	259	21
1891, Aug. 19	Cardiff	Dr. W. Huggins, F.R.S.	189	24
1892, Aug. 3	Edinburgh	Sir A. Geikie, LL.D., F.R.S.	280	14
1893, Sept. 13	Nottingham	Prof. J. S. Burdon Sanderson, F.R.S.	201	17
1894, Aug. 8	Oxford	The Marquis of Salisbury, K.G., F.R.S.	327	21
1895, Sept. 11	Ipswich	Sir Douglas Galton, K.C.B., F.R.S.	214	13
1896, Sept. 16	Liverpool	Sir Joseph Lister, Bart., Pres. R.S.	330	31
1897, Aug. 18	Toronto	Sir John Evans, K.C.B., F.R.S.	120	8
1898, Sept. 7	Bristol	Sir W. Crookes, F.R.S.	281	19
1899, Sept. 13	Dover	Sir Michael Foster, K.C.B., Sec. R.S.	296	20

* Ladies were not admitted by purchased tickets until 1843. † Tickets of Admission to Sections only.

[*Continued on p.* xiv.

ANNUAL MEETINGS.

Old Annual Members	New Annual Members	Associates	Ladies	Foreigners	Total	Amount received for Tickets	Sums paid on account of Grants for Scientific Purposes	Year
—	—	—	—	—	353	—	—	1831
—	—	—	—	—	—	—	—	1832
—	—	—	—	—	900	—	—	1833
—	—	—	—	—	1298	—	£20 0 0	1834
—	—	—	—	—	—	—	167 0 0	1835
—	—	—	—	—	1350	—	435 0 0	1836
—	—	—	—	—	1840	—	922 12 6	1837
—	—	—	1100*	—	2400	—	932 2 2	1838
—	—	—	—	34	1438	—	1595 11 0	1839
—	—	—	—	40	1353	—	1546 16 4	1840
46	317	—	60*	—	891	—	1235 10 11	1841
75	376	33†	331*	28	1315	—	1449 17 8	1842
71	185	—	160	—	—	—	1565 10 2	1843
45	190	9†	260	—	—	—	981 12 8	1844
94	22	407	172	35	1079	—	831 9 9	1845
65	39	270	196	36	857	—	685 16 0	1846
197	40	495	203	53	1320	—	208 5 4	1847
54	25	376	197	15	819	£707 0 0	275 1 8	1848
93	33	447	237	22	1071	963 0 0	159 19 6	1849
128	42	510	273	44	1241	1085 0 0	345 18 0	1850
61	47	244	141	37	710	620 0 0	391 9 7	1851
63	60	510	292	9	1108	1085 0 0	304 6 7	1852
56	57	367	236	6	876	903 0 0	205 0 0	1853
121	121	765	524	10	1802	1882 0 0	380 19 7	1854
142	101	1094	543	26	2133	2311 0 0	480 16 4	1855
104	48	412	346	9	1115	1098 0 0	734 13 9	1856
156	120	900	569	26	2022	2015 0 0	507 15 4	1857
111	91	710	509	13	1698	1931 0 0	618 18 2	1858
125	179	1206	821	22	2564	2782 0 0	684 11 1	1859
177	59	636	463	47	1689	1604 0 0	766 19 6	1860
184	125	1589	791	15	3138	3944 0 0	1111 5 10	1861
150	57	433	242	25	1161	1089 0 0	1293 16 6	1862
154	209	1704	1004	25	3335	3640 0 0	1608 3 10	1863
182	103	1119	1058	13	2802	2965 0 0	1289 15 8	1864
215	149	766	508	23	1997	2227 0 0	1591 7 10	1865
218	105	960	771	11	2303	2469 0 0	1750 13 4	1866
193	118	1163	771	7	2444	2613 0 0	1739 4 0	1867
226	117	720	682	45‡	2004	2042 0 0	1940 0 0	1868
229	107	678	600	17	1856	1931 0 0	1622 0 0	1869
303	195	1103	910	14	2878	3096 0 0	1572 0 0	1870
311	127	976	754	21	2463	2575 0 0	1472 2 6	1871
280	80	937	912	43	2533	2649 0 0	1285 0 0	1872
237	99	796	601	11	1983	2120 0 0	1685 0 0	1873
232	85	817	630	12	1951	1979 0 0	1151 16 0	1874
307	93	884	672	17	2248	2397 0 0	960 0 0	1875
331	185	1265	712	25	2774	3023 0 0	1092 4 2	1876
238	59	446	283	11	1229	1268 0 0	1128 9 7	1877
290	93	1285	674	17	2578	2615 0 0	725 16 6	1878
239	74	529	349	13	1404	1425 0 0	1080 11 11	1879
171	41	389	147	12	915	899 0 0	731 7 7	1880
313	176	1230	514	24	2557	2689 0 0	476 8 1	1881
253	79	516	189	21	1253	1286 0 0	1126 1 11	1882
330	323	952	841	5	2714	3369 0 0	1083 3 3	1883
317	219	826	74	26 & 60 H.§	1777	1855 0 0	1173 4 0	1884
332	122	1053	447	6	2203	2256 0 0	1385 0 0	1885
428	179	1067	429	11	2453	2532 0 0	995 0 6	1886
510	244	1985	493	92	3838	4336 0 0	1186 18 0	1887
399	100	639	509	12	1984	2107 0 0	1511 0 5	1888
412	113	1024	579	21	2437	2441 0 0	1417 0 11	1889
368	92	680	334	12	1775	1776 0 0	789 16 8	1890
341	152	672	107	35	1497	1664 0 0	1029 10 0	1891
413	141	733	439	50	2070	2007 0 0	864 10 0	1892
328	57	773	268	17	1661	1653 0 0	907 15 6	1893
435	69	941	451	77	2321	2175 0 0	583 15 6	1894
290	31	493	261	22	1324	1236 0 0	977 15 5	1895
383	139	1384	873	41	3181	3228 0 0	1104 6 1	1896
286	125	682	100	41	1362	1398 0 0	1059 10 8	1897
327	96	1051	639	33	2446	2399 0 0	1212 0 0	1898
324	68	548	120	27	1403	1328 0 0	1430 14 2	1899

‡ Including Ladies. § Fellows of the American Association were admitted as Hon. Members for this Meeting.

 [*Continued on p.* xv.

Table of

Date of Meeting	Where held	Presidents	Old Life Members	New Life Members
1900, Sept. 5	Bradford	Sir William Turner, D.C.L., F.R.S. ...	267	13
1901, Sept. 11......	Glasgow	Prof. A. W. Rücker, D.Sc., Sec. R.S.	310	37
1902, Sept. 10......	Belfast	Prof. J. Dewar, LL.D., F.R.S.	243	21
1903, Sept. 9	Southport	Sir Norman Lockyer, K.C.B., F.R.S.	250	21
1904, Aug. 17......	Cambridge	Rt. Hon. A. J. Balfour, M.P., F.R.S. ...	419	32
1905, Aug. 15......	South Africa	Prof. G. H. Darwin, LL.D., F.R.S. ...	115	40
1906, Aug. 1	York	Prof. E. Ray Lankester, LL.D., F.R.S.	322	10
1907, July 31	Leicester	Sir David Gill, K.C.B., F.R.S.	276	19
1908, Sept. 2	Dublin.................	Dr. Francis Darwin, F.R.S.	294	24
1909, Aug. 25......	Winnipeg	Prof. Sir J. J. Thomson, F.R.S.	117	13
1910, Aug. 31......	Sheffield	Rev. Prof. T. G. Bonney, F.R.S.	293	26
1911, Aug. 30......	Portsmouth	Prof. Sir W. Ramsay, K.C.B., F.R.S.	284	21
1912, Sept. 4	Dundee	Prof. E. A. Schäfer, F.R.S.	288	14
1913, Sept. 10......	Birmingham	Sir Oliver J. Lodge, F.R.S.	376	40
1914, July–Sept.	Australia...............	Prof. W. Bateson, F.R.S.	172	13
1915, Sept. 7	Manchester	Prof. A. Schuster, F.R.S.	242	19
1916, Sept. 5	Newcastle-on-Tyne	Sir Arthur Evans, F.R.S.	164	12
1917	(No Meeting)		—	—
1918	(No Meeting)		—	—
1919, Sept. 9	Bournemouth.........	Hon. Sir C. Parsons, K.C.B., F.R.S. ...	235	47
1920, Aug. 24......	Cardiff	Prof. W. A. Herdman, C.B.E., F.R.S.	288	11
1921, Sept. 7	Edinburgh	Sir T. E. Thorpe, C.B., F.R.S.	336	9
1922, Sept. 6	Hull	Sir C. S. Sherrington, G.B.E., Pres. R.S.	228	13
1923, Sept. 12......	Liverpool	Sir Ernest Rutherford, F.R.S.	326	12
1924, Aug. 6	Toronto	Sir David Bruce, K.C.B., F.R.S.	119	7
1925, Aug. 26......	Southampton	Prof. Horace Lamb, F.R.S.	280	8
1926, Aug. 4	Oxford	H.R.H. The Prince of Wales, K.G., F.R.S.	358	9
1927, Aug. 31......	Leeds	Sir Arthur Keith, F.R.S..................	249	9
1928, Sept. 5	Glasgow	Sir William Bragg, K.B.E., F.R.S. ...	260	10
1929, July 22	South Africa	Sir Thomas Holland, K.C.S.I., K.C.I.E., F.R.S.	81	1
1930, Sept. 3	Bristol	Prof. F. O. Bower, F.R.S.	221	5
1931, Sept. 23......	London	Gen. the Rt. Hon. J. C. Smuts, P.C., C.H., F.R.S.	487	14
1932, Aug. 31	York	Sir Alfred Ewing, K.C.B., F.R.S.	206	1
1933, Sept. 6	Leicester	Sir F. Gowland Hopkins, Pres. R.S. ...	185	37

[1] Including 848 Members of the South African Association.
[2] Including 137 Members of the American Association.
[3] Special arrangements were made for Members and Associates joining locally in Australia, see Report, 1914, p. 686. The numbers include 80 Members who joined in order to attend the Meeting of L'Association Française at Le Havre.
[4] Including Students' Tickets, 10s.
[5] Including Exhibitioners granted tickets without charge.

Annual Meetings—(continued).

Old Annual Members	New Annual Members	Associates	Ladies	Foreigners	Total	Amount received for Tickets	Sums paid on account of Grants for Scientific Purposes	Year
297	45	801	482	9	1915	£1801 0 0	£1072 10 0	1900
374	131	794	246	20	1912	2046 0 0	920 9 11	1901
314	86	647	305	6	1620	1644 0 0	947 0 0	1902
319	90	688	365	21	1754	1762 0 0	845 13 2	1903
449	113	1338	317	121	2789	2650 0 0	887 18 11	1904
937[1]	411	430	181	16	2130	2422 0 0	928 2 2	1905
356	93	817	352	22	1972	1811 0 0	882 0 9	1906
339	61	659	251	42	1647	1561 0 0	757 12 10	1907
465	112	1166	222	14	2297	2317 0 0	1157 18 8	1908
290[2]	162	789	90	7	1468	1623 0 0	1014 9 9	1909
379	57	563	123	8	1449	1439 0 0	963 17 0	1910
349	61	414	81	31	1241	1176 0 0	922 0 0	1911
368	95	1292	359	88	2504	2349 0 0	845 7 6	1912
480	149	1287	291	20	2643	2756 0 0	978 17 1	1913
139	4160[3]	539[3]	—	21	5044[3]	4873 0 0	1861 16 4[6]	1914
287	116	628[4]	141	8	1441	1406 0 0	1569 2 8	1915
250	76	251[4]	73	—	826	821 0 0	985 18 10	1916
—	—	—	—	—	—	—	677 17 2	1917
—	—	—	—	—	—	—	326 13 3	1918
254	102	688[4]	153	3	1482	1736 0 0	410 0 0	1919
Old Annual Regular Members	Annual Members: Meeting and Report	Annual Members: Meeting only	Transferable Tickets	Students' Tickets				
136	192	571	42	120	20	1380	1272 10 0	1251 13 0[8]	1920
133	410	1394	121	343	22	2768	2599 15 0	518 1 10	1921
90	294	757	89	235[5]	24	1730	1699 5 0	772 0 7	1922
					Complimentary[7]				
123	380	1434	163	550	308	3296	2735 15 0	777 18 6[9]	1923
37	520	1866	41	89	139	2818	3165 19 0[10]	1197 5 9	1924
97	264	878	62	119	74	1782	1630 5 0	1231 0 0	1925
101	453	2338	169	225	69	3722	3542 0 0	917 1 6	1926
84	334	1487	82	264	161	2670	2414 5 0	761 10 0	1927
76	554	1835	64	201	74	3074	3072 10 0	1259 10 0	1928
24	177	1227[11]	—	161	83	1754	1477 15 0	1838 2 1	1929
68	310	1617	97	267	54	2639	2481 15 0	683 5 7	1930
78	656	2994	157	454	449	5702[12]	4792 10 0	1146 7 6	1931
44	226	1163	45	214	125	2024	1724 5 0	1183 13 11	1932
39	236	1468	82	147	74	2268	2428 2 0	412 19 11[13]	1933

[6] Including grants from the Caird Fund in this and subsequent years.
[7] Including Foreign Guests, Exhibitioners, and others.
[8] The Bournemouth Fund for Research, initiated by Sir C. Parsons, enabled grants on account of scientific purposes to be maintained.
[9] Including grants from the Caird Gift for research in radioactivity in this and subsequent years to 1926.
[10] Subscriptions paid in Canada were $5 for Meeting only and others pro rata; there was some gain on exchange.
[11] Including 450 Members of the South African Association.
[12] Including 413 tickets for certain meetings, issued at 5*s*. to London County Council school-teachers.
[13] For nine months ending March 31, 1933.

INSTALLATION OF THE PRESIDENT

JANUARY 6, 1933.

ON Friday, January 6, 1933, at Birkbeck College, London, on the occasion of the joint meeting of Organising Sectional Committees, Sir Frederick Gowland Hopkins, Pres. R.S., was installed in the Presidency of the Association in succession to Sir Alfred Ewing, K.C.B., F.R.S.

Sir Alfred Ewing said that under the new statute of the Association, which came into effect a year ago, the President came into office in January and held it throughout the year. It was an excellent rule, for it educated the President in the work of the Association and its various committees before his chief duty fell to be performed at the Annual Meeting in the autumn. There was no need for him to say how fortunate the Association was in securing Sir Frederick Hopkins as President—a man already so pre-eminent as to be President of the Royal Society. Last year it had been, so to speak, the turn of that part of science which dealt with the constitution of non-living matter and with purely mechanical processes, which can certainly kill, but cannot make alive. Now they turned, perhaps with relief and greater hope, to the still more difficult science of life—of whose fascinating problems no one could speak with more authority and clearer discernment than Sir Frederick Hopkins. One felt certain that in his hands the Association would lose nothing of the public attention and interest its great annual conference continued to command. More than ever, he believed, the public wished to know about the advances of science—partly because these were now confessedly tentative and incomplete, and partly also because they might provide some guidance in the urgent perplexities of our social affairs.

It seemed not unlikely, and probably it was desirable, that in future meetings of the Association scientists would make a more conscious effort to relate their studies to social problems. Science was now playing so large a part in human life, both for good and for evil, that they could not logically stand aloof: they were bound to recognise the immense consequence of discovery and invention, not only on man's philosophy but on his habits of living and his relations to his fellows. Science had brought new powers, and with them new dangers—grave dangers of which the community were scarcely yet aware. It was clearly the duty of science to point these out. The first step towards escape from these dangers was to have them fully realised.

NARRATIVE OF THE LEICESTER MEETING.

On Wednesday, September 6, at 8.30 P.M. the Inaugural General Meeting was held in the De Montfort Hall, when the Rt. Worshipful the Lord Mayor of Leicester (Councillor Arthur Hawkes, J.P.) welcomed the Association to Leicester, and the President of the Association, Sir Frederick Gowland Hopkins, Pres. R.S., delivered an Address (for which see p. 1), entitled *Some Chemical Aspects of Life*.

On Friday, September 8, in the Great Hall of Wyggeston Boys' School, at 8.15 P.M., Sir Josiah Stamp, G.B.E., General Treasurer of the Association, delivered an Evening Discourse entitled *Must Science ruin Economic Progress?* (for an abstract of which see p. 578).

On Monday, September 11, in the Lancaster Hall, at 8.15 P.M., Prof. Jocelyn F. Thorpe, C.B.E., F.R.S., delivered an Evening Discourse, with cinematograph and illustrations and experiments, entitled *The Work of the Safety in Mines Research Board* (for an abstract of which see p. 584).

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Public Lectures were given by Sir Henry Fowler, K.B.E., on Tuesday, September 5, on *Transport for a Century*, and by Prof. Julian Huxley, on Saturday, September 9, on *Ants and Men*.

* * * * * *

The Lord Mayor and Lady Mayoress of the City of Leicester (Councillor Arthur Hawkes, J.P., and Mrs. Hawkes) entertained members of the Association at a Reception in the De Montfort Hall on Thursday evening, September 7.

The President (His Grace the Duke of Rutland), the Chairman (Sir Jonathan North), the Principal and Members of the College Council of University College, Leicester, entertained members of the Association at a Garden Party in the grounds of University College on Monday afternoon, September 11.

The President (Mr. H. Percy Gee, J.P.) and Council of the Leicester Literary and Philosophical Society entertained members of the Association at a Reception in the City Art Gallery and Museum on Tuesday evening, September 12.

Numerous other institutions and works in the city and neighbourhood afforded facilities and entertainment to members during the meeting.

An exhibition indicating the value of planning in connection with modern problems in town and country was held under the joint auspices of the Council for the Preservation of Rural England, the University College, Leicester, and Section E (Geography) of the Association, and helped to illustrate papers read in the Section.

An exhibition of machinery, scientific instruments, and electrical instruments was held in connection with Section G (Engineering), and consisted of products of firms in Leicester and Leicestershire.

* * * * * *

A special service was held in the Cathedral on Sunday, September 10, when officers and other members of the Association accompanied the Lord Mayor (Councillor Arthur Hawkes) and the City Council in state from the Town Hall. The preacher was the Rt. Rev. the Lord Bishop of Carlisle (whose sermon was published in the *Church Times*, September 15). An official Free Church service and other special services were held.

* * * * * *

On Saturday, September 9, general excursions took place to Charnwood Forest; Stanton Ironworks, Holwell; Kenilworth and Warwick; Stratford-on-Avon (where one party witnessed a performance of *Macbeth* at the Memorial Theatre); Belvoir Castle (by kind permission of the Duke of Rutland). Among other excursions and visits, those devoted to the interests of special Sections are mentioned among the Sectional Transactions in later pages.

* * * * * *

At the final meeting of the General Committee, on Tuesday, September 12, it was resolved:

That the British Association most warmly thanks the City and County of Leicester for their hospitable reception. It deeply appreciates the unsparing efforts of the Lord Mayor and Corporation, and of the Local Officers and Committees, in making arrangements for the convenience of the meetings and for the comfort of visiting members, as also the judicious choice and admirable organisation of the excursions. The thanks of the Association are further due to the many institutions, works, and individuals in the City and neighbourhood for their generous aid in securing the success of the Meeting; and the support of the citizens of Leicester who have joined the Association as members is very gratefully recognised.

On Wednesday, September 13, the President and General Secretaries and certain other members waited upon the Lord Mayor (Councillor Arthur Hawkes) at the Town Hall, in order to take formal leave of him and other local officers for the Meeting.

REPORT OF THE COUNCIL, 1932–33.

OBITUARY.

I.—The Council has had to deplore the loss by death of the following office-bearers and supporters :—

Dr. G. C. Bourne, F.R.S.	Sir Philip Magnus
G. R. Carline	Sir Daniel Morris, K.C.M.G.
A. Chaston Chapman, F.R.S.	Sir Ronald Ross, K.C.B., K.C.M.G., F.R.S.
Sir Dugald Clerk, K.B.E., F.R.S.	Rev. Dr. A. H. Sayce
Prof. T. Craib	Lt.-Col. J. Stephenson, C.I.E., F.R.S.
Dr. J. E. Crombie	Sir J. Arthur Thomson
Prof. J. C. Fields, F.R.S.	Prof. W. C. Unwin, F.R.S.
Sir Walter Fletcher, K.B.E., F.R.S.	A. Silva White
Bernard Hobson	Dr. A. Wilmore
Sir Everard im Thurn, K.C.M.G., C.B.	

Dr. J. E. Crombie's and Mr. Bernard Hobson's benefactions to the Association are referred to in a later paragraph.

REPRESENTATION.

II.—Representatives of the Association have been appointed as follows :—

Sixth International Congress on Scientific Management	Mr. R. J. Mackay
American Association for the Advancement of Science, annual meeting, 1932–33	Prof. W. F. G. Swann
University of London : laying of foundation stone of new buildings . .	The President
Royal Society of Teachers, conference on research	Mr. J. L. Holland
Royal Cornwall Polytechnic Society, centenary	Dr. G. C. Simpson, C.B., F.R.S.
Board of Trade Discussion on Conference of International Bureau of Weights and Measures	Dr. Ezer Griffiths, F.R.S.

RESOLUTIONS.

III.—Resolutions referred by the General Committee to the Council for consideration, and, if desirable, for action were dealt with as follows. The resolutions will be found in the Report for 1932, pp. xliii–xliv.

(*a*) The recommendation from Section C (Geology) concerning the photography of certain special topographical features in north-east Yorkshire and elsewhere was referred to the Air Ministry, but this authority was unable to take the action desired.

(*b*) Following upon recommendations from Sections E (Geography) and M (Agriculture), a deputation waited upon the Ministry of Agriculture, and was assured that as far as possible the publication of *Agricultural Statistics*, Parts 1 and 2, should be expedited, and the needs of students in agricultural geography should be met.

(*c*) The attention of the Home Office and the Ministry of Transport was called to the resolution from Section G (Engineering) concerning the desirability of action against noises caused by motor vehicles.

(*d*) The Council conveyed to the Museums Association their approval of the system of interchange of specimens in museums, and expressed the hope that the system would be extended. (Resolution of Section H, Anthropology.)

(*e*) A recommendation that the final report of the Colour Vision Committee should be communicated to the Ministry of Transport, in so far as it referred to the shape of traffic lights, was adopted. The report was communicated accordingly, and certain information was supplied to the Ministry at its request.

The Council forwarded the following resolution to H.M. Secretary of State for the Colonies:—

The Council of the British Association have noted with great interest the highly important archæological and geological discoveries made in the Kendu-Homa area of Kenya Colony, and the promise they give that even more valuable results will be obtained there in the future. The Council therefore express the strong hope that it may be possible to reserve the superficial deposits of this area (which at a minimum may be taken as a strip two miles in width from the shore, from Kendu Point to Homa Point, on Lake Victoria, a distance of 12 miles) for excavation only by qualified scientific investigators.

Down House.

IV.—The following report for the year 1932–33 has been received from the Down House Committee:—

The number of visitors to Down House during the year ending June 6, 1933, has been 7,022, compared with 7,638 in 1931–32, and 5,210 in 1930–31. The decrease during the present as compared with last year is accounted for by the fact that last year included the Association's centenary week, when a large number of members visited the house.

Among recent acquisitions reference should be made to the barometer used by Darwin on the voyage of H.M.S. *Beagle*, which has been placed at Down House by the Royal Society on loan. It has been restored to working order by Messrs. Negretti & Zambra, with the kind advice of the Meteorological Office.

Darwin's dining-room table has been added to the collection by purchase.

The Old Study was copied as nearly as possible, and with great success, as one of the rooms of scientific men exhibited at the Ideal Home Exhibition this year.

The Committee have acknowledged with deep gratitude a gift of £150 a year for five years from the Pilgrim Trust to the funds of the Association in respect of its trusteeship under Sir Buckston Browne's gift of Down House. The preliminary steps which led to the making of this gift were

taken by Sir Alfred Ewing during the year of his presidency of the Association.

The following financial statement shows income on account of Down House, and current expenditure, for the financial year ending March 31, 1933, compared with that for the year ending June 30, 1932. The overlap between the two years is accounted for by the recent change of dates for the Association's financial year.

The figure for income from the Endowment Fund during the past year is in a measure deceptive as certain dividends have been paid gross, which previously were paid less tax to be subsequently reclaimed ; so that this year includes both a gross payment and a refund on the preceding year. The gross amount of interest and dividends for a full year is £994 10*s*.

Income	1931-32			1932-33		
	£	*s.*	*d.*	£	*s.*	*d.*
By Dividends on endowment fund	741	4	5	776	16	3
,, Income tax recovered	223	15	2	253	5	7
,, Rents	137	0	0	138	0	0
,, Donations	9	19	1	7	4	4
,, Sale of Postcards and Catalogues	33	16	7	24	17	0
,, Balance, being excess of expenditure (running costs), as below, over income	150	13	2	40	7	11½
	£1,296	8	5	1,240	11	1½

Expenditure (*running costs*)

	1931-32			1932-33		
	£	*s.*	*d.*	£	*s.*	*d.*
To Wages and National Insurance	840	10	11	807	2	10
,, Rates, Land Tax, Insurances	72	4	0	64	10	11
,, Coal, Coke, etc.	125	16	2	104	9	9
,, Water	14	10	6	15	6	8
,, Lighting and Drainage Plants (including petrol and oil)	50	12	1	69	17	6
,, Repairs and Renewals	41	1	6	39	8	7
,, Garden Materials	47	7	2	58	10	9
,, Household Requisites	16	5	6	16	19	3½
,, Transport and Carriage	4	4	6	5	5	2
,, Auditors	33	10	0	22	10	10
,, Postcards and Catalogues (printing)	44	6	11	9	0	0*
,, Postages, Telephone, Stationery, etc.	5	19	2	27	8	10
* Approx.	£1,296	8	5	1,240	11	1½

'*Capital*' *Expenditure*, 1932-33

	£	*s.*	*d.*
Improvement of drainage system	36	15	0
,, ,, stokehole	12	14	6
Radiator alterations	16	0	0
	£65	9	6

In connection with so-called 'capital' expenditure by the Association upon Down House, detailed in last year's report, the statement was then made that the works of restoration, etc., included under this heading were within sight of completion. They have now been completed, and the 'capital' expenditure account has been closed at the total sum of £3,292 15*s.* 2*d.*, including catalogues in stock £110 (£119 less approximate cost of catalogues sold, £9).

The Council have granted a lease of the cottage of Homefield to Sir Arthur and Lady Keith or the survivor of them, and have authorised Sir Arthur Keith to make agreed improvements in the property and structural additions to the cottage at his own charges. They have also granted an annual tenancy of a piece of land about three-quarters of an acre in extent to the Royal College of Surgeons.

Finance.

V.—The Council have received reports from the General Treasurer throughout the year. His accounts have been audited and are presented to the General Committee. As the General Committee last year adopted a proposal that the financial year of the Association should run from April 1 to March 31, the present audited accounts cover a period of nine months after June 20, 1932, the close of the last financial year under the former plan. A *pro formâ* account of expenditure and income for the year as from April 1, 1932, has therefore been added.

Expenditure from Lt.-Col. Alan Cunningham's bequest for the preparation of new mathematical tables in the theory of numbers has been made or sanctioned as follows :—Purchase of calculating machine; preparation of tables of ideal numbers (Dr. E. L. Ince); publication of Factor Table to 100,000.

The Council have been informed that the Seismology Committee of the Association is a prospective beneficiary in the sum of £1,000 under the will of Dr. J. E. Crombie.

They have also been informed that the Association is a beneficiary in the sum of £1,000 under the will of Mr. Bernard Hobson, 'to be invested and the proceeds annually devoted to the promoting of definite geological research, the trust fund to be called the Bernard Hobson Fund.' The Council propose that they should administer this fund, that it shall be competent for the Committee of Section C (Geology) to recommend grants as a charge upon the fund, and that grants may be made from it in response to special applications arising in the course of any year.

The Council recommend that a sum not exceeding £400 should be allocated to grants to Research Committees from general funds for the ensuing year.

President (1934), General Officers, Council and Committees.

VI.—The Council nominate as President of the Association for the year 1934 (Aberdeen Meeting) Sir William Bate Hardy, F.R.S.

VII.—*The General Officers* have been nominated by the Council as follows :—

General Treasurer, Sir Josiah Stamp, G.B.E.
General Secretaries, Prof. F. J. M. Stratton, O.B.E., Prof. P. G. H. Boswell, O.B.E., F.R.S.

VIII.—*Council.*—The retiring Ordinary Members of the Council are: Sir Daniel Hall, K.C.B., F.R.S., Mr. A. R. Hinks, C.B.E., F.R.S., Sir Henry Lyons, F.R.S., Prof. E. B. Poulton, F.R.S., Prof. A. C. Seward, F.R.S.

The Council have nominated as new members Dr. F. Aveling, Prof. R. N. Rudmose Brown, Prof. F. Balfour Browne, leaving two vacancies to be filled by the General Committee without nomination by the Council.

The full list of nominations of Ordinary Members is as follows :—

Dr. F. Aveling
Dr. F. A. Bather, F.R.S.
Prof. R. N. Rudmose Brown
Prof. F. Balfour Browne
Sir Henry Dale, C.B.E., Sec.R.S.
Prof. J. Drever
Dr. A. Ferguson
Prof. R. B. Forrester
Sir Henry Fowler, K.B.E.
Prof. W. T. Gordon
Prof. Dame Helen Gwynne-Vaughan, G.B.E.
Dr. H. S. Harrison
Sir James Henderson
Dr. C. W. Kimmins
Sir P. Chalmers Mitchell, C.B.E., F.R.S.
Dr. C. Tate Regan, F.R.S.
Sir John Russell, O.B.E., F.R.S.
Dr. N. V. Sidgwick, F.R.S.
Dr. G. C. Simpson, C.B., F.R.S.
Prof. J. F. Thorpe, C.B.E., F.R.S.
H. T. Tizard, C.B., F.R.S.
Prof. A. M. Tyndall, F.R.S.
Prof. F. E. Weiss, F.R.S.

IX.—*General Committee.*—Dr. R. E. Gibbs, Dr. C. C. Hurst, Capt. W. N. McClean, Prof. A. G. Ogilvie, Dr. Edgar Stedman, Mrs. Ellen Stedman, and Mr. H. E. Wimperis, C.B.E., have been admitted as members of the General Committee.

X.—*Corresponding Societies Committee.*—The Corresponding Societies Committee has been nominated as follows :—The President of the Association (*Chairman ex-officio*), Mr. T. Sheppard (*Vice-Chairman*), Dr. C. Tierney (*Secretary*), the General Treasurer, the General Secretaries, Mr. C. O. Bartrum, Dr. F. A. Bather, F.R.S., Sir Richard Gregory, F.R.S., Mr. J. V. Pearman, Sir David Prain, F.R.S., Sir John Russell, F.R.S., Prof. W. M. Tattersall.

GENERAL TREASURER'S ACCOUNT, 1932-33.

THE General Committee at the York Meeting last year adopted the Council's proposal that the financial year of the Association should run from April 1 to March 31, instead of from July 1 to June 30 as heretofore. The audited accounts herewith, therefore, cover a period of nine months only, from July 1, 1932 (the previous accounts having been completed to June 30 of that year), to March 31, 1933. The usual figures for comparison with the preceding year are omitted from these accounts.

The auditors have furnished the following notes :

Members' Subscriptions (Annual) are mainly in respect of sales of tickets at the York Meeting, 1932. Preliminary programmes for the ensuing meeting are not issued until April ; therefore the advance sale of tickets does not materially affect the present account.

Advertisements are chiefly on printed matter for the Meeting (programmes, &c.). At the date of the accounts these are not completed. The revenue shown in the nine months accounts is, therefore, practically nil.

Dividends credited in the accounts are the actual amounts received, some being in respect of six months, some nine months and others twelve months. The dividends credited to General Income and Expenditure Account are on balance short by £21 0s. 6*d*. In the case of the Caird Income and Expenditure Account, the majority of the dividends are for twelve months, and on balance there is an actual excess of £46 19*s*. 4*d*. This also applies to Down House, where the amount of excess is £31 6*s*. 3*d*.

Income Tax Recovered credited in accounts is the actual amount received and is for twelve months.

Dividends received Gross.—During the period certain dividends (on Government Stocks) were received gross instead of net. The additional amounts included in the accounts, which would in a normal way be included in Income Tax Recovered in the following year, amount to :

General Income and Expenditure Account	£128	6	4
Caird Income and Expenditure Account . . .	11	9	10
Cunningham Bequest	8	9	9
Down House Income and Expenditure Account	30	18	9

Bonus on Conversion of War Stocks credited in the accounts is non-recurring.

Donations to Centenary Fund credited in the accounts, £62 16*s*. 6*d*., are also non-recurring.

Yarrow Fund Realisation. The amount credited to Income and Expenditure Account, £156, is not according to scale. It is normally at the rate of approximately £340 p.a.

General Expenses includes £100 for special accountants' fees in connection with the Centenary Meeting, 1931.

Grants.—The amount included in the accounts is in respect of grants actually paid. The further grants which have been authorised but

not yet claimed amount to £152 0s. 1d. on General Account, and £100 Caird Fund. These are noted on the accounts. The majority of these grants will, it is expected, be claimed before August 31 next.

In order to afford a clearer idea of the past year's working, a *pro formâ* account of expenditure and income on general funds for the *year* ending March 31, in the simplest form, is appended to the audited accounts. The comparative figures there given are the averages (with slight adjustments) used by the Council when considering their report on finance to the General Committee last year.

Some of the above remarks by the auditors apply to this *pro formâ* account equally. On the side of expenditure, general expenses are higher than the average, owing mainly to the non-recurrent special accountants' fees referred to. It is hoped that the excess of expenditure over income on account of Down House will not recur, thanks to the generous gift of the Pilgrim Trustees to which reference is made in the report of the Council. The reduction of printing costs anticipated in last year's Report of the Council is taking effect ; on the other hand no material reduction in the increased costs of postage can be expected under present conditions. On the side of income, reference has been made above to non-recurrent items, and to the fact that the full normal realisation of capital from the Yarrow Fund (which was heavily drawn upon in connection with the Centenary Meeting in 1931) has not been given effect. The receipts from sale of publications have fallen, owing in part to the reductions of prices authorised last year. The growth of advertisement revenue, under the existing conditions of depression, cannot be expected to continue. The receipts from membership subscriptions were much below the average of the preceding ten years.

Nevertheless, after taking into consideration all the items in the account which are either abnormal or non-recurrent, it is estimated that, omitting those items, the account would have been approximately balanced, even if there had been charged upon it a full year's transfer of £500 to the Contingency Fund. But if the position appears so far satisfactory, it must be emphasised that the Association is still restricted in its activities by insufficient funds : it has always to be remembered that the Yarrow Fund is a wasting asset ; and the Association is in no position (without trenching further upon its capital) to meet all the applications for assistance of important researches and other scientific activities which are brought before it every year. The expansion of the Association's membership and the strengthening of its financial foundations should be the object of all those who would further its interests.

JOSIAH C. STAMP,
General Treasurer.

Balance Sheet,

LIABILITIES.

	£ s. d.	£ s. d.
To *General Fund*—		
As at July 1, 1932		
As per contra		10,942 19 1
(Subject to depreciation in value of Investments)		
,, *Caird Fund*—		
As at July 1, 1932		
As per contra		9,582 16 3
(Subject to depreciation in value of Investments)		
,, *Caird Fund Revenue Account*—		
Balance at July 1, 1932	192 0 0	
Less Excess of Expenditure over Income for the nine months	33 1 4	
as per contra		158 18 8
(Contingent liability for grants authorised at York Meeting, 1932, but not yet claimed, £100)		
,, *Sir Charles Parsons' Gift*—		
As per contra		10,000 0 0
,, *Sir Alfred Yarrow's Gift*—		
As per last Account	6,298 14 8	
Less Transferred to Income and Expenditure Account under terms of the Gift	156 0 0	
as per contra		6,142 14 8
,, *Life Compositions*—		
As per last Account	2,087 2 2	
Add received during year	37 10 0	
	2,124 12 2	
Less Transferred to Income and Expenditure Account	45 0 0	
as per contra		2,079 12 2
,, *Toronto University Presentation Fund*—		
As per last Account	182 18 10	
Add Dividends	4 7 6	
Bonus on Conversion	1 15 0	
	189 1 4	
Less Awards given	6 2 6	
as per contra		182 18 10
,, *Lt.-Col. A. J. C. Cunningham's Bequest*—		
For the preparation of New Tables in the Theory of Numbers.		
As per last Account	3,007 19 0	
Add—		
Income Tax recovered for 12 months ended June 30, 1932	32 3 10	
Dividends	78 7 5	
	3,118 10 3	
Less Grant made	150 0 0	
as per contra		2,968 10 3
To *Down House Endowment Fund*—		
As per contra		20,000 0 0
Carried forward		£62,058 9 11

March 31, 1933.

ASSETS.

	£ s. d.	£ s. d.
By *General Fund*—		
Investments as per Schedule (p. xxxiv)	10,888 10 2	
Cash at Bank	54 8 11	10,942 19 1
,, *Caird Fund*—		
Investments as per Schedule (p. xxxiv)		9,582 16 3
,, *Caird Fund Revenue Account*—		
Cash at Bank		158 18 8
,, *Sir Charles Parsons' Gift*—		
Investment as per Schedule (p. xxxiv)		10,000 0 0
,, *Sir Alfred Yarrow's Gift*—		
Investment as per Schedule (p. xxxiv)		6,142 14 8
,, *Life Compositions*—		
Investments as per Schedule (p. xxxiv) . . .		2,079 12 2
,, *Toronto University Presentation Fund*—		
Investments as per Schedule (p. xxxv) . . .	178 11 4	
Cash at Bank	4 7 6	182 18 10
,, *Lt.-Col. A. J. C. Cunningham's Bequest*—		
Investments as per Schedule (p. xxxv) . . .	2,702 19 2	
Cash at Bank	265 11 1	2,968 10 3
,, *Sir Buckston Browne's Gift* in memory of Darwin—Down House, Kent		Not valued.
Do. Endowment Fund—		
Investments as per Schedule (p. xxxv		20,000 0 0
Carried forward . .		£62,058 9 11

Balance Sheet,

LIABILITIES—*continued.*

				£ s. d.	£ s. d.
Brought forward					62,058 9 11
To REVENUE ACCOUNT—					
Sundry Creditors				119 6 4	
Do. Do. (Down House)				22 16 11	
,, *Income and Expenditure Account—*					
Balance at July 1, 1932			7,017 4 5		
Less Unexpended Grant in aid of Expenses, 1929 (South African Meeting), not recoverable	74 5 0				
Less Excess of Expenditure over Income for the nine months	184 2 6				
		258 7 6			
				6,758 16 11	
Contingency Fund				375 0 0	
					7,276 0 2
(Contingent liability for grants authorised at York Meeting, 1932, but not yet claimed, £152 0s. 1*d.*)					£69,334 10 1

I have examined the foregoing Account with the Books and Vouchers and certify the Investments, and have inspected the Deeds of Down House and the Mortgage on

Approved.

ARTHUR L. BOWLEY, W. W. WATTS } *Auditors.*

1933.

March 31, 1933—*continued.*

ASSETS—*continued.*

	£ s. d.	£ s. d.
Brought forward		62,058 9 11
By REVENUE ACCOUNT—		
Investments as per Schedule (p. xxxv)	5,604 16 0	
,, Down House Suspense Account—		
As per last Account	938 7 0	
Purchase of Land adjoining Down House	275 0 0	
Stock of Catalogues at Down House	110 0 0	
Sundry Debtors and Payments in advance	70 6 1	
Do. (Down House)	20 11 9	
Cash at Bank	204 3 6	
Do. in Hand	52 15 10	
		7,276 0 2
		£69,334 10 1

the same to be correct. I have also verified the Balances at the Bankers and Isleworth House.

W. B. Keen, *Chartered Accountant.*

Income and

FOR THE NINE MONTHS

EXPENDITURE.

	£ s. d.	£ s. d.
To Heat, Lighting and Power	23 5 1	
,, Stationery	46 13 3	
,, Rent	15 0	
,, Postages	135 12 8	
,, Travelling Expenses	166 18 2	
,, Exhibitioners	53 5 6	
,, General Expenses	323 17 5	
	750 7 1	
,, Salaries and Wages	1,474 16 9	
,, Pension Contribution (1 year)	75 0 0	
,, Printing, Binding, etc.	943 9 3	
		3,243 13 1
,, Grants to Research Committees:—		
Film Committee	2 0 0	
General Science in School	15 19 11	
Biology of a Tropical River in British Guiana	20 0 0	
		37 19 11
(Grants authorised at the York Meeting, 1932, but not yet claimed amount to £152 0s. 1d.)		
To Balance, being excess of Income over Expenditure for the nine months		179 19 7
		£3,461 12 7

	£ s. d.
,, Contingency Fund Amount allocated in accordance with Council Minute, i.e. £500 p.a., Proportion for nine months	375 0 0
	£375 0 0

Expenditure Account

ENDED MARCH 31, 1933

INCOME.

	£ s. d.	£ s. d.
By Annual Regular Members, including £11 for 1933/4		90 13 0
,, Annual Temporary Members, including £22 1s. for 1933/4		922 17 0
,, Annual Members with Report, including £18 10s. for 1933/4		213 10 0
,, Transferable Tickets		47 10 0
,, Students' Tickets		93 10 0
,, Life Compositions, Amount transferred		45 0 0
,, Sale of Publications		402 8 10
,, Advertisement Revenue		4 4 1
,, Income Tax recovered for 12 months ended 30 June, 1932		288 7 9
,, Unexpended Balance of Grants, returned		16 5 10
,, Liverpool Exhibitioners		22 10 0
,, Dividends:—		
Consols 2½ per cent. Stock	116 0 1	
India 3 per cent. Stock	74 5 0	
Great Indian Peninsula Railway 'B' Annuity	26 10 11	
4½ per cent. Conversion Loan	48 18 6	
Ditto Sir Charles Parsons' Gift	393 15 0	
3 per cent. Local Loans	60 16 8	
3½ per cent. War Loan	37 11 3	
Ditto Ditto (Series A), Sir Alfred Yarrow's Gift	157 9 4	
3½ per cent. Conversion Loan	81 12 8	
		996 19 5
,, Sir Alfred Yarrow's Gift—		
Amount transferred		156 0 0
Bonus on Conversion of War Stock—Sir A. Yarrow's Gift	62 19 8	
Do. Do. Other	18 10 6	
		81 10 2
,, Interest on Mortgage		17 10 0
,, Sundry Donations: Centenary Fund		62 16 6
		£3,461 12 7

	£ s. d.
By Balance brought down	179 19 7
,, Down House Income and Expenditure Account—Balance, being Excess of Income over Expenditure for the nine months transferred	10 17 11
,, Balance transferred to Balance Sheet	184 2 6
	£375 0 0

Caird Fund, Income

For the Nine Months

EXPENDITURE.

	£ s. d.	£ s. d.
To Grants paid—		
Seismology Committee	100 0 0	
Zoological Record Committee	50 0 0	
Derbyshire Caves Committee	50 0 0	
Plymouth Table Committee	50 0 0	
Athlit Caves Investigation	75 0 0	
Freshwater Biological Station Committee	50 0 0	
		375 0 0
(Grants authorised at the York Meeting, 1932, but not yet claimed amount to £100)		
		£375 0 0

Down House Income

For the Nine Months

EXPENDITURE.

	£ s. d.	£ s. d.
To Wages of Staff (net)	607 1 3	
,, Rates, Insurance, etc.	49 9 0	
,, Coal, Coke, etc.	95 0 3	
,, Lighting and Drainage (including oil and petrol)	54 0 3	
,, Water	11 9 4	
,, Repairs and Renewals	28 9 4	
,, Garden Material, etc.	41 14 1	
,, Household Requisites, etc.	9 16 6	
,, Transport and Carriage	1 2 11	
,, Accountants' Fees	22 10 10	
,, Printing, Postages, Telephone, Stationery, etc.	19 11 8	
		940 5 5
To Balance carried down		76 7 5
		£1,016 12 10
To Repairs and alterations to Buildings, etc.		65 9 6
,, Balance, being Excess of Income over Expenditure for the nine months		10 17 11
		£76 7 5

and Expenditure Account

ENDED MARCH 31, 1933

INCOME.

	£ s. d.	£ s. d.
By Dividends—		
India 3½ per cent. Stock	63 4 1	
Canada 3½ per cent. Stock	65 12 6	
London, Midland & Scottish Railway Consolidated 4 per cent. Preference Stock	47 5 0	
Southern Railway Consolidated 5 per cent. Preference Stock	75 0 0	
		251 1 7
,, Income Tax recovered for 12 months ended 30th June 1932		90 17 1
,, Balance, being excess of Expenditure over Income for 9 months		33 1 4
		£375 0 0

NOTE—

Balance at 1 July 1932	192 0 0
Less Excess of Expenditure as above	33 1 4
Balance at date as per Balance Sheet	158 18 8

and Expenditure Account

ENDED MARCH 31, 1933

INCOME.

	£ s. d.	£ s. d.
By Rents Receivable		103 10 0
,, Income Tax recovered for the 12 months ended June 30, 1932		253 5 7
,, Dividends—		
4½ per cent. India Stock	123 15 0	
Fishguard & Rosslare Railway 3½ per cent. Stock	78 15 0	
New South Wales 5 per cent. Stock	46 17 6	
Great Western Railway 5 per cent. Stock	125 5 0	
Australia 5 per cent. Stock 1945/75	93 15 0	
Western Australia 5 per cent. Stock	93 15 0	
Birkenhead Railway 4 per cent. Stock	75 0 0	
		637 2 6
,, Donations		5 7 3
,, Sale of Postcards, etc.		17 7 6
		£1,016 12 10
By Balance brought down		76 7 5
		£76 7 5

Schedules of Investments, etc.

General Funds—	£	s.	d.
£4,651 10s. 5d. Consolidated 2½ per cent. Stock at cost	3,942	3	3
£3,600 India 3 per cent. Stock at cost	3,522	2	6
£879 14s. 9d. Great Indian Peninsula Railway 'B' Annuity at cost	827	15	0
£52 12s. 7d. War Stock (Post Office Issue) at cost	54	5	2
£834 16s. 6d. 4½ per cent. Conversion Stock at cost	835	12	4
£1,400 War Stock 3½ per cent. at cost	1,393	16	11
£94 7s. 4½ per cent. Conversion Stock at cost	62	15	0
£326 9s. 10d. 3½ per cent. Conversion Stock at cost	250	0	0
(Value at date, £10,311 6s. 8d.)	£10,888	10	2

Caird Fund—	£	s.	d.
£2,627 0s. 10d. India 3½ per cent. Stock at cost	2,400	13	3
£2,100 London Midland & Scottish Railway Consolidated 4 per cent. Preference Stock at cost	2,190	4	3
£2,500 Canada 3½ per cent. Registered Stock 1930/50 at cost	2,397	1	6
£2,000 Southern Railway Consolidated 5 per cent. Preference Stock at cost	2,594	17	3
(Value at date, £7,159 7s. 11d.)	£9,582	16	3

Sir Charles Parsons' Gift—	£	s.	d.
£10,300 4½ per cent. Conversion Stock at cost	£10,000	0	0
(Value at date, £11,458 15s.)			

Sir Alfred Yarrow's Gift—	£	s.	d.
£6,142 14s. 8d. 3½ per cent. War Loan	£6,142	14	8
(Value at date, £6,219 10s. 4d.)			

Life Compositions—	£	s.	d.
£2,949 12s. 4d. Local Loans at cost	1,923	12	2
£156 3½ per cent. War Loan	156	0	0
(Value at date, £2,783 2s. 2d.)	£2,079	12	2

Schedules of Investments, etc.—*continued*

Toronto University Presentation Fund—

	£	s.	d.
£175 3½ per cent. War Loan at cost	178	11	4
(Value at date, £177 3*s*. 9*d*.)			

Lt.-Col. A. J. Cunningham's Bequest—

£1,187 6*s*. 10*d*. Consolidated Stock 2½ per cent.	653	0	9
£300 Port of London 3½ per cent. Stock 1949/99	216	0	0
£100 Commonwealth of Australia 4¾ per cent. Stock	93	0	0
£100 New Zealand 5 per. cent Stock	103	0	0
£800 India 6 per cent. Stock at cost	801	12	0
£1,274 4*s*. 10*d*. Local Loans 3 per cent. Stock at cost	836	6	5
(Value at date, £3,359 18*s*. 7*d*.)	£2,702	19	2

Down House Endowment Fund—

£5,500 India 4½ per cent. Stock 1958/68 at cost	5,001	17	4
£2,500 Australia 5 per cent. 1945/75 at cost	2,468	19	0
£3,000 Fishguard and Rosslare Railway 3½ per cent. Guaranteed Preference Stock at cost	2,139	17	3
£2,500 New South Wales 5 per cent. Stock 1945/65 at cost	2,467	7	9
£2,500 Western Australia 5 per cent. Stock 1945/75 at cost	2,472	1	6
£3,340 Great Western Railway 5 per cent. Guaranteed Stock at cost	3,436	7	5
£2,500 Birkenhead Railway 4 per cent. Consolidated Stock at cost	2,013	9	9
(Value at date, £22,540 6*s*.)	£20,000	0	0

Revenue Account—

£2,098 1*s*. 9*d*. Consolidated 2½ per cent. Stock at cost	1,200	0	0
£4,338 6*s*. 2*d*. Conversion 3½ per cent. Stock at cost	3,300	0	0
£400 3½ per cent. War Loan Inscribed Stock at cost	404	16	0
Second Mortgage on Isleworth House, Orpington, Kent	700	0	0
(Value of Stocks at date, £6,353 18*s*. 10*d*.)	£5,604	16	0

Pro formâ Account of Income

FOR THE YEAR APRIL 1, 1932—

EXPENDITURE

Averages, £		£	s.	d.
24	To Heat, light, and power	29	9	10
75	,, Stationery	57	14	7
1	,, Rent	1	0	0
170	,, Postages	217	14	2½
160	,, Travelling expenses	187	6	1
52	,, Exhibitioners	53	5	6
210	,, General expenses	371	3	5
2,026	,, Salaries and Wages	1,958	0	9
75	,, Pension contribution	75	0	0
1,700	,, Printing, binding, etc.	1,186	6	4
—	,, Grants to Research Committees from general funds	259	14	11
—	,, Down House, excess of expenditure over income (including 'capital' expenditure)	105	17	5½
	,, Transfer to Contingency Fund (nine months)	375	0	0
		£4,877	13	1

Down House accounts for the year will be found in the

and Expenditure (General Funds)

—MARCH 31, 1933

INCOME

Averages, £				£	s.	d.
2,500	By Annual Membership subscriptions			1,933	15	0
—	,, Life compositions, amount transferred			45	0	0
566	,, Sale of publications			477	5	2½
242	,, Advertisement revenue			357	5	3
—	,, Unexpended balances of grants, returned			16	5	10
22	,, Liverpool exhibitioners			22	10	0
—	,, Centenary Fund donations			93	1	6
250	,, Income tax recovered for 1931–32			288	7	9
—	,, Bonus on conversion of War Stock			81	10	2
	,, Interest and dividends	£1.335 19 0				
	,, Interest on mortgage	26 5 0				
	,, Sir Alfred Yarrow's gift, capital transferred	156 0 0				
1,577				1,518	4	0
—	,, Excess of expenditure over income for the year			44	8	4½
				£4,877	13	1

Report of the Council (Down House Committee's report).

RESEARCH COMMITTEES, Etc.

APPOINTED BY THE GENERAL COMMITTEE, MEETING IN LEICESTER, 1933.

Grants of money, if any, from the Association for expenses connected with researches are indicated in heavy type.

SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCES.

Seismological Investigations.—Dr. F. J. W. Whipple (*Chairman*), Mr. J. J. Shaw, C.B.E. (*Secretary*), Prof. P. G. H. Boswell, O.B.E., F.R.S., Dr. C. Vernon Boys, F.R.S., Sir F. W. Dyson, K.B.E., F.R.S., Dr. Wilfred Hall, Dr. H. Jeffreys, F.R.S., Prof. Sir Horace Lamb, F.R.S., Mr. A. W. Lee, Prof. H. M. Macdonald, F.R.S., Prof. E. A. Milne, M.B.E., F.R.S., Mr. R. D. Oldham, F.R.S., Prof. H. H. Plaskett, Prof. H. C. Plummer, F.R.S., Prof. A. O. Rankine, O.B.E., Rev. J. P. Rowland, S.J., Mr. D. H. Sadler, Prof. R. A. Sampson, F.R.S., Mr. F. J. Scrase, Capt. H. Shaw, Sir Frank Smith, K.C.B., C.B.E., Sec. R.S., Dr. R. Stoneley, Mr. E. Tillotson, Sir G. T. Walker, C.S.I., F.R.S. **£100** (Caird Fund grant).

Calculation of Mathematical Tables.—Prof. E. H. Neville (*Chairman*), Dr. L. J. Comrie (*Secretary*), Prof. A. Lodge (*Vice-Chairman*), Dr. J. R. Airey, Prof. R. A. Fisher, F.R.S., Dr. J. Henderson, Dr. E. L. Ince, Dr. J. O. Irwin, Dr. J. C. P. Miller, Dr. E. S. Pearson, Mr. F. Robbins, Mr. D. H. Sadler, Dr. A. J. Thompson, Dr. J. F. Tocher, Dr. J. Wishart. **£100.**

SECTIONS A, E, G.—MATHEMATICAL AND PHYSICAL SCIENCES, GEOGRAPHY, ENGINEERING.

To inquire into the position of Inland Water Survey in the British Isles and the possible organisation and control of such a survey by central authority.—Vice-Adml. Sir H. P. Douglas, K.C.B., C.M.G. (*Chairman*), Lt.-Col. E. Gold, D.S.O., F.R.S. (*Vice-Chairman*), Capt. W. N. McClean (*Secretary*), Mr. E. G. Bilham, Dr. Brysson Cunningham, Prof. C. B. Fawcett, Dr. A. Ferguson, Dr. Ezer Griffiths, F.R.S., Mr. W. T. Halcrow, Mr. T. Shirley Hawkins, O.B.E., Mr. W. J. M. Menzies, Mr. H. Nimmo, Dr. A. Parker, Mr. D. Ronald, Capt. J. C. A. Roseveare, Dr. Bernard Smith, F.R.S., Mr. C. Clemesha Smith, Mr. F. O. Stanford, O.B.E., Brig. H. S. L. Winterbotham, C.M.G., D.S.O., Capt. J. G. Withycombe, Dr. S. W. Wooldridge. **£40.**

SECTIONS A, J.—MATHEMATICAL AND PHYSICAL SCIENCES, PSYCHOLOGY.

The possibility of quantitative estimates of Sensory Events.—Dr. A. Ferguson (*Chairman*), Dr. C. S. Myers, C.B.E., F.R.S. (*Vice-Chairman*), Mr. R. J. Bartlett (*Secretary*), Dr. H. Banister, Prof. F. C. Bartlett, F.R.S., Dr. Wm. Brown, Dr. N. R. Campbell, Dr. S. Dawson, Prof. J. Drever, Mr. J. Guild, Dr. R. A. Houstoun, Dr. J. O. Irwin, Dr. G. W. C. Kaye, Dr. S. J. F. Philpott, Dr. L. F. Richardson, F.R.S., Dr. J. H. Shaxby, Mr. T. Smith, F.R.S., Dr. R. H. Thouless, Dr. W. S. Tucker, O.B.E.

SECTION C.—GEOLOGY.

To excavate Critical Sections in the Palæozoic Rocks of England and Wales.—Prof. W. W. Watts, F.R.S. (*Chairman*), Prof. W. G. Fearnsides, F.R.S. (*Secretary*), Mr. W. S. Bisat, Dr. H. Bolton, Prof. W. S. Boulton, Dr. E. S.

Cobbold, Prof. A. H. Cox, Mr. E. E. L. Dixon, Dr. Gertrude Elles, M.B.E., Prof. E. J. Garwood, F.R.S., Prof. H. L. Hawkins, Prof. G. Hickling, Prof. V. C. Illing, Prof. O. T. Jones, F.R.S., Prof. J. E. Marr, F.R.S., Dr. F. J. North, Dr. J. Pringle, Dr. T. F. Sibly, Dr. W. K. Spencer, F.R.S., Prof. A. E. Trueman, Dr. F. S. Wallis. **£20** (Caird Fund, contingent grant).

The Collection, Preservation, and Systematic Registration of Photographs of Geological Interest.—Prof. E. J. Garwood, F.R.S. (*Chairman*), Prof. S. H. Reynolds (*Secretary*), Mr. C. V. Crook, Mr. J. F. Jackson, Mr. J. Ranson, Prof. W. W. Watts, F.R.S., Mr. R. J. Welch.

To investigate Critical Sections in the Tertiary and Cretaceous Rocks of the London Area. To tabulate and preserve records of new excavations in that area.—Prof. W. T. Gordon (*Chairman*), Dr. S. W. Wooldridge (*Secretary*), Mr. H. C. Berdinner, Prof. P. G. H. Boswell, O.B.E., F.R.S., Miss M. C. Crosfield, Mr. F. Gosling, Prof. H. L. Hawkins, Prof. G. Hickling. **£15.**

The Stratigraphy and Structure of the Palæozoic Sedimentary Rocks of West Cornwall.—Mr. H. Dewey (*Chairman*), Mr. E. H. Davison (*Secretary*), Mr. H. G. Dines, Miss E. M. Lind Hendriks, Mr. S. Hall, Dr. S. W. Wooldridge.

To consider and report upon Petrographic Classification and Nomenclature.—Dr. H. H. Thomas, F.R.S. (*Chairman*), Dr. A. K. Wells (*Secretary*), Prof. E. B. Bailey, F.R.S., Prof. P. G. H. Boswell, O.B.E., F.R.S., Prof. A. Brammall, Dr. R. Campbell, Prof. A. Holmes, Prof. A. Johannsen, Dr. W. Q. Kennedy, Dr. A. G. MacGregor, Prof. P. Niggli, Prof. H. H. Read, Prof. S. J. Shand, Mr. W. Campbell Smith, Prof. C. E. Tilley, Dr. G. W. Tyrrell, Dr F. Walker. **£5.**

To prove the character of the Palæozoic Rocks underlying the Carboniferous of the Craven area.—Prof. W. G. Fearnsides, F.R.S. (*Chairman*), Dr. R. G. S. Hudson (*Secretary*), Prof. O. T. Jones, F.R.S., Prof. W. B. R. King, O.B.E., Mr. W. H. Wilcockson. **£30** (Bernard Hobson Fund grant).

SECTIONS C, E.—GEOLOGY, GEOGRAPHY.

To administer a grant in support of a topographical and geological survey of the Lake Rudolph area in E. Africa.—Sir Albert E. Kitson, C.M.G., C.B.E. (*Chairman*), Dr. A. K. Wells (*Secretary*), Mr. S. J. K. Baker, Prof. F. Debenham, Dr. V. Fuchs, Prof. W. T. Gordon, Brig. H. S. L. Winterbotham, C.M.G., D.S.O. **£35.**

SECTION D.—ZOOLOGY.

Zoological Bibliography and Publication.—Prof. E. B. Poulton, F.R.S. (*Chairman*), Dr. F. A. Bather, F.R.S. (*Secretary*), Mr. E. Heron-Allen, F.R.S., Dr. W. T. Calman, F.R.S., Sir P. Chalmers Mitchell, C.B.E., F.R.S., Mr. W. L. Sclater.

To nominate competent Naturalists to perform definite pieces of work at the Marine Laboratory, Plymouth.—Prof. J. H. Ashworth, F.R.S. (*Chairman and Secretary*), Prof. H. Graham Cannon, Prof. H. Munro Fox, Prof. J. Stanley Gardiner, F.R.S. **£50** (Caird Fund grant).

To co-operate with other Sections interested, and with the Zoological Society, for the purpose of obtaining support for the Zoological Record.—Sir Sidney Harmer, K.B.E., F.R.S. (*Chairman*), Dr. W. T. Calman, F.R.S. (*Secretary*), Prof. E. S. Goodrich, F.R.S., Prof. D. M. S. Watson, F.R.S. **£50** (Caird Fund grant).

To consider the position of Animal Biology in the School Curriculum and matters relating thereto.—Prof. R. D. Laurie (*Chairman and Secretary*), Mr. H. W. Ballance, Prof. E. W. MacBride, F.R.S., Miss M. McNicol, Miss A. J. Prothero, Prof. W. M. Tattersall, Dr. E. N. Miles Thomas.

To determine the behaviour of a limited and uniform plankton population observed under natural conditions.—Dr. G. P. Bidder (*Chairman*), Mr. A. C. Gardiner (*Secretary*), Dr. J. Gray, F.R.S., Mr. J. T. Saunders. **£3 10s. 6d.** (Unexpended balance).

The biology of a tropical river in British Guiana and of the neighbouring districts.—Prof. J. S. Gardiner, F.R.S. (*Chairman*), Dr. G. S. Carter and Mr. J. T. Saunders (*Secretaries*), Dr. W. T. Calman, F.R.S., Prof. J. Graham Kerr, F.R.S., Dr. C. Tate Regan, F.R.S.

SECTIONS D, I, K.—ZOOLOGY, PHYSIOLOGY, BOTANY.

To aid competent investigators selected by the Committee to carry on definite pieces of work at the Zoological Station at Naples.—Prof. J. H. Ashworth, F.R.S. (*Chairman and Secretary*), Prof. J. Barcroft, C.B.E., F.R.S., Prof. E. W. MacBride, F.R.S., Dr. Margery Knight. **£50** (Caird Fund grant).

SECTIONS D, K.—ZOOLOGY, BOTANY.

To aid competent investigators selected by the Committee to carry out definite pieces of work at the Freshwater Biological Station, Wray Castle, Windermere.—Prof. F. E. Fritsch, F.R.S. (*Chairman*), Mr. J. T. Saunders (*Secretary*), Miss P. M. Jenkin, Dr. C. H. O'Donoghue (*from Section D*); Dr. W. H. Pearsall (*from Section K*). **£75** (£40 Caird Fund grant).

SECTION E.—GEOGRAPHY.

To co-operate with the Ordnance Survey in the production of a Population Density Map (or Maps) of Great Britain and to endeavour to get this published as soon as the 1931 Census is available; and, further, to examine the possibility of making similar Maps of the Empire, utilising the International Map (1 : 1,000,000) as the base.—Brig. H. S. L. Winterbotham, C.M.G., D.S.O. (*Chairman*), Capt. J. G. Withycombe (*Secretary*), Mr. J. Bartholomew, Lt.-Col. A. B. Clough, Prof. F. Debenham, Prof. C. B. Fawcett, Prof. H. J. Fleure, Mr. H. King, Mr. R. H. Kinvig, Prof. A. G. Ogilvie, O.B.E., Prof. O. H. T. Rishbeth, Prof. P. M. Roxby, Mr. A. Stevens.

To inquire into the present state of knowledge of the Human Geography of Tropical Africa, and to make recommendations for furtherance and development.—Prof. P. M. Roxby (*Chairman*), Prof. A. G. Ogilvie, O.B.E. (*Secretary*), Dr. A. Geddes (*Assistant Secretary*), Mr. S. J. K. Baker, Prof. C. B. Fawcett, Prof. H. J. Fleure, Mr. E. B. Haddon, Mr. R. H. Kinvig, Mr. J. McFarlane, Col. M. N. MacLeod, D.S.O., Prof. J. L. Myres, O.B.E., F.B.A., Mr. R. A. Pelham, Mr. R. U. Sayce, Rev. E. W. Smith, Brig. H. S. L. Winterbotham, C.M.G., D.S.O. **£5.**

To investigate the mapping of historical data for medieval England and to take steps to advance such work.—Mr. J. N. L. Baker (*Chairman*), Dr. H. C. Darby, Mr. E. W. Gilbert, Mr. F. G. Morris, Dr. S. W. Wooldridge.

SECTIONS E, K.—GEOGRAPHY, BOTANY.

To complete two maps of England on the 1/M. scale showing (i) the distribution of woodland (based on physical evidence) after the establishment of climatic conditions approximating to the present, and (ii) the distribution of woodland on the basis of evidence derived from early topographical writings and maps.—Sir John Russell, O.B.E., F.R.S. (*Chairman*), Prof. P. M. Roxby (*Secretary*); Prof. H. J. Fleure, Mr. R. H. Kinvig, Prof. A. G. Ogilvie, O.B.E., Brig. H. S. L. Winterbotham, C.M.G., D.S.O., Capt. J. G. Withycombe (*from Section E*); Prof. E. J. Salisbury, Dr. T. W. Woodhead (*from Section K*). **£25.**

SECTIONS E, L.—GEOGRAPHY, EDUCATION.

To report on the present position of Geographical Teaching in Schools, and of Geography in the training of teachers; to formulate suggestions for a syllabus for the teaching of geography both to Matriculation Standard and

in Advanced Courses and to report, as occasion arises, to Council through the Organising Committee of Section E upon the practical working of Regulations issued by the Board of Education (including the Scottish Education Department) affecting the position of Geography in Schools and Training Colleges.—Prof. Sir T. P. Nunn (*Chairman*), Mr. L. Brooks (*Secretary*), Mr. A. B. Archer, Mr. J. N. L. Baker, Mr. C. C. Carter, Prof. H. J. Fleure, Dr. O. J. R. Howarth, O.B.E., Mr. H. E. M. Icely, Mr. J. McFarlane, Rt. Hon. Sir Halford J. Mackinder, P.C., Prof. J. L. Myres, O.B.E., F.B.A., Dr. Marion Newbigin, Prof. A. G. Ogilvie, O.B.E., Mr. A. Stevens, Prof. C. B. Fawcett (*from Section E*) ; Mr. J. L. Holland, Sir R. Gregory, Bt., F.R.S., Mr. E. R. Thomas, Miss O. Wright, Prof. Godfrey Thomson (*from Section L*).

SECTION F.—ECONOMIC SCIENCE AND STATISTICS.

Chronology of the World Crisis from 1929 onwards.—Prof. J. H. Jones (*Chairman*), Dr. P. Ford (*Convener*), Mr. G. N. Clark, Prof. H. M. Hallsworth, C.B.E., Mr. R. F. Harrod, Mr. A. Radford, Prof. J. G. Smith.

SECTIONS F, G, I, J, L.—ECONOMIC SCIENCE AND STATISTICS, ENGINEERING, PHYSIOLOGY, PSYCHOLOGY, EDUCATION.

Industrial Co-operation : to report on the provisions for co-ordinating and stimulating scientific work bearing on business practice, and to make recommendations.—Dr. J. A. Bowie (*Chairman*), Mr. R. J. Mackay (*Secretary*), Prof. J. G. Smith, Major L. Urwick (*from Section F*) ; Prof. W. Cramp (*from Section G*) ; Mr. G. P. Crowden (*from Section I*) ; Dr. C. S. Myers, C.B.E., F.R.S. (*from Section J*) ; Sir Richard Gregory, Bt., F.R.S. (*from Section L*).

SECTION G.—ENGINEERING.

Earth Pressures.—Mr. F. E. Wentworth-Sheilds, O.B.E. (*Chairman*), Dr. J. S. Owens (*Secretary*), Prof. G. Cook, Mr. T. E. N. Fargher, Prof. A. R. Fulton, Prof. F. C. Lea, Prof. R. V. Southwell, F.R.S., Dr. R. E. Stradling, Dr. W. N. Thomas, Mr. E. G. Walker, Mr. J. S. Wilson. **£9 5s. 3d.** (Unexpended balance).

Electrical Terms and Definitions.—Prof. Sir J. B. Henderson (*Chairman*), Prof. F. G. Baily and Prof. G. W. O. Howe (*Secretaries*), Prof. W. Cramp, Prof. W. H. Eccles, F.R.S., Prof. C. L. Fortescue, Sir R. Glazebrook, K.C.B., F.R.S., Prof. A. E. Kennelly, Prof. E. W. Marchant, Sir Frank Smith, K.C.B., C.B.E., Sec. R.S., Prof. L. R. Wilberforce.

Stresses in Overstrained Materials.—Sir Henry Fowler, K.B.E. (*Chairman*), Dr. J. G. Docherty (*Secretary*), Prof. G. Cook, Prof. B. P. Haigh, Mr. J. S. Wilson. **£10** (Unexpended balance).

To review the knowledge at present available for the reduction of noise, and the nuisances to the abatement of which this knowledge could best be applied.—Sir Henry Fowler, K.B.E. (*Chairman*), Prof. T. R. Cave-Brown-Cave, C.B.E. (*Secretary*), Mr. R. S. Capon, Prof. G. W. O. Howe. **£10.**

SECTION H.—ANTHROPOLOGY.

To report on the Distribution of Bronze Age Implements.—Prof. J. L. Myres, O.B.E., F.B.A. (*Chairman*), Mr. H. J. E. Peake (*Secretary*), Mr. A. Leslie Armstrong, Mr. H. Balfour, F.R.S., Mr. L. H. Dudley Buxton, Prof. V. Gordon Childe, Mr. O. G. S. Crawford, Prof. H. J. Fleure, Dr. Cyril Fox.

To report on the Classification and Distribution of Rude Stone Monuments in the British Isles.—Mr. H. J. E. Peake (*Chairman*), Dr. Margaret A. Murray (*Secretary*), Mr. A. L. Armstrong, Mr. H. Balfour, F.R.S., Prof. V. Gordon Childe, Dr. Cyril Fox, Mr. T. D. Kendrick.

To report on the probable sources of the supply of Copper used by the Sumerians, —Mr. H. J. E. Peake (*Chairman*), Dr. C. H. Desch, F.R.S. (*Secretary*), Mr. H. Balfour, F.R.S., Mr. L. H. Dudley Buxton, Prof. V. Gordon Childe, Mr. O. Davies, Prof. H. J. Fleure, Sir Flinders Petrie, F.R.S., Dr. R. H. Rastall.

To conduct Archæological and Ethnological Researches in Crete.—Prof. J. L. Myres, O.B.E., F.B.A. (*Chairman*), Mr. L. Dudley Buxton (*Secretary*), Dr. W. L. H. Duckworth, Sir A. Evans, F.R.S., Dr. F. C. Shrubsall.

To co-operate with the Torquay Antiquarian Society in investigating Kent's Cavern.—Sir A. Keith, F.R.S. (*Chairman*),Prof. J. L. Myres, O.B.E., F.B.A. (*Secretary*), Mr. M. C. Burkitt, Dr. R. V. Favell, Miss D. A. E. Garrod, Mr. A. D. Lacaille. **£5.**

To co-operate with a Committee of the Royal Anthropological Institute in the exploration of Caves in the Derbyshire district.—Mr. M. C. Burkitt (*Chairman*), Dr. R. V. Favell (*Secretary*), Mr. A. Leslie Armstrong, Prof. H. J. Fleure, Miss D. A. E. Garrod, Dr. J. Wilfrid Jackson, Prof. L. S. Palmer, Mr. H. J. E. Peake. **£25** (Caird Fund grant).

To co-operate with Miss Caton-Thompson in her researches in prehistoric sites in the Western Desert of Egypt.—Prof. J. L. Myres, O.B.E., F.B.A. (*Chairman*), Mr. H. J. E. Peake (*Secretary*), Mr. H. Balfour, F.R.S.

To report to the Sectional Committee on the question of re-editing 'Notes and Queries in Anthropology.'—Dr. H. S. Harrison (*Chairman*), Mr. L. Dudley Buxton (*Secretary*), Miss R. M. Fleming, Prof. C. Daryll Forde, Dr. A. C. Haddon, F.R.S., Capt. T. A. Joyce, O.B.E., Prof. C. G. Seligman, F.R.S., Mrs. Seligman, Miss C. Wedgwood.

To carry out the excavation of Palæolith cave deposits on Mt. Carmel, Palestine. —Prof. J. L. Myres, O.B.E., F.B.A. (*Chairman*), Mr. M. C. Burkitt (*Secretary*), Miss G. Caton-Thompson, Miss D. A. E. Garrod, **£30.**

To carry out research among the Ainu of Japan.—Prof. C. G. Seligman, F.R.S. (*Chairman*), Mrs. C. G. Seligman (*Secretary*), Dr. H. S. Harrison, Capt. T. A. Joyce, O.B.E., Rt. Hon. Lord Raglan. **£50.**

To co-operate with the local committee in the excavation of Pen Dinas hill fort, Cardiganshire.—Dr. Cyril Fox (*Chairman*), Mr. V. E. Nash-Williams (*Secretary*), Prof. V. Gordon Childe, Prof. C. Daryll Forde, Rt. Hon. Lord Raglan, Dr. R. E. M. Wheeler. **£25.**

To excavate a prehistoric and Roman mining site in Rio Tinto, Spain.—Mr. M. C. Burkitt (*Chairman*), Dr. C. H. Desch, F.R.S. (*Secretary*), Prof. V. Gordon Childe, Dr. Margaret A. Murray, Prof. J. L. Myres, O.B.E., F.B.A. **£15** (Caird Fund, contingent grant).

To investigate blood groups among the Tibetans.—Prof. H. J. Fleure (*Chairman*), Prof. R. Ruggles Gates, F.R.S. (*Secretary*), Dr. J. H. Hutton, C.I.E., Mr. R. U. Sayce.

SECTION I.—PHYSIOLOGY.

The supply of Oxygen at high altitudes.—Prof. J. Barcroft, C.B., F.R.S. (*Chairman*), Dr. Raymond Greene (*Acting Secretary*), Mr. G. S. Adair, Mr. E. N. Odell, Major J. A. Sadd. **£5.**

To deal with the use of a Stereotactic Instrument.—Prof. J. Mellanby, F.R.S. (*Chairman and Secretary*).

SECTIONS I, J.—PHYSIOLOGY, PSYCHOLOGY.

The conditions of vertigo and its relation to disorientation.— (*Chairman*), (*Secretary*), Prof. J. H. Burn, Dr. R. S. Creed, Squadron-Leader E. D. Dickson, Prof. J. Drever, Dr. J. T. MacCurdy. **£20.**

SECTION J.—PSYCHOLOGY.

To develop tests of the routine manual factor in mechanical ability.—Dr. C. S. Myers, C.B.E., F.R.S. (*Chairman*), Dr. G. H. Miles (*Secretary*), Prof. C. Burt, Dr. F. M. Earle, Dr. Ll. Wynn Jones, Prof. T. H. Pear. **£20** (Caird Fund, contingent grant).

The nature of perseveration and its testing.—Prof. F. Aveling (*Chairman*), Mr. E. Farmer (*Secretary*), Prof. F. C. Bartlett, F.R.S., Dr. Mary Collins, Dr. W. Stephenson.

SECTION K.—BOTANY.

Transplant Experiments.—Sir Arthur Hill, K.C.M.G., F.R.S. (*Chairman*), Dr. W. B. Turrill (*Secretary*), Prof. F. W. Oliver, F.R.S., Prof. E. J. Salisbury, Prof. A. G. Tansley, F.R.S.

Fossil Plants at Fort Gray, near East London.—Dr. A. W. Rogers, F.R.S. (*Chairman*), Prof. R. S. Adamson (*Secretary*), Prof. A. C. Seward, F.R.S.

The anatomy of timber-producing trees.—Prof. H. S. Holden (*Chairman*), Dr. Helen Bancroft (*Secretary*), Prof. J. H. Priestley, D.S.O. **£10.**

SECTION L.—EDUCATIONAL SCIENCE.

To consider the position of science teaching in Adult Education classes, and to suggest possible means of promoting through them closer contact between scientific achievement and social development.—Prof. J. L. Myres, O.B.E., F.B.A. (*Chairman*), Mr. C. E. Browne (*Secretary*), Major A. G. Church, D.S.O., Dr. Lilian J. Clarke, Miss E. R. Conway, C.B.E., Prof. C. H. Desch, F.R.S., Mr. A. Clow Ford, Sir Richard Gregory, Bt., F.R.S., Mr. S. R. Humby, Dr. C. W. Kimmins, Miss H. Masters, Mr. E. R. Thomas. **£10.**

To consider and report on the possibility of the Section undertaking more definite work in promoting educational research.—Dr. W. W. Vaughan (*Chairman*), (*Secretary*), Miss H. Masters, Mr. E. R. B. Reynolds, Mr. N. F. Sheppard. **£5.**

SECTIONS M, E.—AGRICULTURE, GEOGRAPHY.

To co-operate with the staff of the Imperial Soil Bureau to examine the soil resources of the Empire.—Sir John Russell, O.B.E., F.R.S. (*Chairman*), Mr. G. V. Jacks (*Secretary*), Dr. E. M. Crowther, Dr. W. G. Ogg, Prof. G. W. Robinson (*from Section M*) ; Prof. C. B. Fawcett, Mr. H. King, Dr. L. D. Stamp, Mr. A. Stevens, Dr. S. W. Wooldridge (*from Section E*).

CORRESPONDING SOCIETIES.

Corresponding Societies Committee.—The President of the Association (*Chairman ex-officio*), Mr. T. Sheppard (*Vice-Chairman*), Dr. C. Tierney (*Secretary*), the General Secretaries, the General Treasurer, Mr. C. O. Bartrum, Dr. F. A. Bather, F.R.S., Sir Richard Gregory, Bt., F.R.S., Mr. J. V. Pearman, Sir David Prain, C.I.E., C.M.G., F.R.S., Sir John Russell, O.B.E., F.R.S., Prof. W. M. Tattersall.

RESOLUTIONS & RECOMMENDATIONS.

The following resolutions and recommendations were referred to the Council by the General Committee at the Leicester Meeting for consideration and, if desirable, for action :—

From the General Officers.

That it be a recommendation to the General Committee to request the Council to consider by what means the Association, within the framework of its constitution, may assist towards a better adjustment between the advance of Science and social progress, with a view to further discussion at the Aberdeen Meeting.

From Section D (Zoology).

That the Committee of Section D (Zoology) of the British Association regards with grave apprehension the continuing spread of the Musk Rat in the British Isles. It has learned with satisfaction that steps are now being taken by the Ministry of Agriculture and Fisheries to deal with the pest, and it earnestly hopes that no effort will be spared to exterminate the species completely in this country.

From Section E (Geography).

(1) That the Council be asked to urge upon the proper authorities the desirability of including population maps in the Census returns.

(2) That the Council be asked to draw the attention of His Majesty's Government to the backward state of geodetic surveys in the British Colonies and Dependencies, and to point out to the Government that the lack of reliable surveys and maps greatly delays scientific and material progress.

(3) That the Council be asked to approach His Majesty's Government with a view to accelerating the revision of the large scale maps of the Ordnance Survey.

From Section K (Botany).

That in view of the value of the cricket-bat willow as a subsidiary farm crop, which can be grown satisfactorily by the small farmer as well as by the estate owner, the Government be asked to facilitate investigations of the diseases or pests causing 'speck,' 'stain,' and 'water-mark.'

From Section L (Educational Science).

That 1,000 copies of each of the reports on Science in Adult Education and on General Science with special reference to Biology be reprinted and placed on sale at the price of sixpence per copy, and that free copies be distributed to the Press and to a selection of local education authorities and schools.

The following recommendation was approved for immediate action :—

From Section E (Geography).

That copies of the printed report on the Position of Geography in Dominion Universities be circulated to the universities in the Dominions.

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.
LEICESTER, 1933.

THE PRESIDENTIAL ADDRESS

SOME CHEMICAL ASPECTS OF LIFE

BY
SIR FREDERICK GOWLAND HOPKINS, PRES.R.S.,
PRESIDENT OF THE ASSOCIATION.

I.

THE British Association returns to Leicester with assurance of a welcome as warm as that received twenty-six years ago, and of hospitality as generous. The renewed invitation and the ready acceptance speak of mutual appreciation born of the earlier experience. Hosts and guests have to-day reasons for mutual congratulations. The Association on its second visit finds Leicester altered in important ways. It comes now to a city duly chartered and the seat of a bishopric. It finds there a centre of learning, many fine buildings which did not exist on the occasion of the first visit, and many other evidences of civic enterprise. The citizens of Leicester on the other hand will know that since they last entertained it the Association has celebrated its centenary, has four times visited distant parts of the Empire, and has maintained unabated through the years its useful and important activities.

In 1907 the occupant of the Presidential Chair was, as you know, Sir David Gill, the eminent astonomer who, unhappily, like many who listened to his address, is with us no more. Sir David dealt in that address with aspects of science characterised by the use of very exact measurement. The exactitude which he prized and praised has since been developed by modern physics and is now so great that its methods have real æsthetic beauty. In contrast I have to deal with a branch of experimental science which, because it is concerned with living organisms, is in respect of measurement on a different plane. Of the very essence of biological systems is an ineludable complexity, and exact measurement calls for conditions here unattainable. Many may think, indeed, though I am

not claiming it here, that in studying Life we soon meet with aspects which are non-metrical. I would have you believe, however, that the data of modern Biochemistry which will be the subject of my remarks were won by quantitative methods fully adequate to justify the claims based upon them.

Though speculations concerning the origin of Life have given intellectual pleasure to many, all that we yet know about it is that we know nothing. Sir James Jeans once suggested, though not with conviction, that it might be a disease of matter—a disease of its old age! Most biologists, I think, having agreed that Life's advent was at once the most improbable and the most significant event in the history of the Universe, are content for the present to leave the matter there.

We must recognise, however, that Life has one attribute that is fundamental. Whenever and wherever it appears the steady increase of entropy displayed by all the rest of the Universe is then and there arrested. There is no good evidence that in any of its manifestations life evades the second law of thermodynamics, but in the downward course of the energy-flow it interposes a barrier and dams up a reservoir which provides potential for its own remarkable activities. The arrest of energy degradation in living Nature is indeed a primary biological concept. Related to it, and of equal importance is the concept of Organisation.

It is almost impossible to avoid thinking and talking of life in this abstract way, but we perceive it, of course, only as manifested in organised material systems, and it is in them we must seek the mechanisms which arrest the fall of energy. Evolution has established division of labour here. From far back the wonderfully efficient functioning of structures containing chlorophyll has, as everyone knows, provided the trap which arrests and transforms radiant energy—fated otherwise to degrade—and so provides power for nearly the whole living world. It is impossible to believe, however, that such a complex mechanism was associated with life's earliest stages. Existing organisms illustrate what was perhaps an earlier method. The so-called autotrophic bacteria obtain energy for growth by the catalysed oxidation of materials belonging wholly to the inorganic world; such as sulphur, iron or ammonia, and even free hydrogen. These organisms dispense with solar energy, but they have lost in the evolutionary race because their method lacks economy. Other existing organisms, certain purple bacteria, seem to have taken a step towards greater economy, without reaching that of the green cell. They dispense with free oxygen and yet obtain energy from the inorganic world. They control a process in which carbon dioxide is reduced and hydrogen sulphide simultaneously oxidised. The molecules of the former are activated by solar energy

which their pigmentary equipment enables these organisms to arrest.

Are we to believe that life still exists in association with systems that are much more simply organised than any bacterial cell? The very minute filter-passing viruses which, owing to their causal relations with disease, are now the subject of intense study, awaken deep curiosity with respect to this question. We cannot yet claim to know whether or not they are living organisms. In some sense they grow and multiply, but, so far as we yet know with certainty, only when inhabitants of living cells. If they are nevertheless living, this would suggest that they have no independent power of obtaining energy and so cannot represent for us the earliest forms in which life appeared. At present, however, judgment on their biological significance must be suspended. The fullest understanding of all the methods by which energy may be acquired for life's processes is much to be desired.

In any case every living unit is a transformer of energy however acquired, and the Science of Biochemistry is deeply concerned with these transformations. It is with aspects of that science that I am to deal and if to them I devote much of my address my excuse is that since it became a major branch of inquiry Biochemistry has had no exponent in the Chair I am fortunate enough to occupy.

As a progressive scientific discipline it belongs to the present century. From the experimental physiologists of the last century it obtained a charter, and, from a few pioneers of its own, a promise of success; but for the furtherance of its essential aim that century left it but a small inheritance of facts and methods. By its essential or ultimate aim I myself mean an adequate and acceptable description of molecular dynamics in living cells and tissues.

II.

When this Association began its history in 1831 the first artificial synthesis of a biological product was, as you will remember, but three years old. Primitive faith in a boundary between the organic and the inorganic which could never be crossed, was only just then realising that its foundations were gone. Since then, during the century of its existence, the Association has seen the pendulum swing back and forth between frank physico-chemical conceptions of life and various modifications of vitalism. It is characteristic of the present position and spirit of science that sounds of the long conflict between mechanists and vitalists are just now seldom heard. It would almost seem, indeed, that tired of fighting in a misty atmosphere each has retired to his tent to await with wisdom the light of further knowledge. Perhaps, however, they are returning to the fight disguised as Determinist and

Indeterminist respectively. If so the outcome will be of great interest. In any case I feel fortunate in a belief that what I have to say will not, if rightly appraised, raise the old issues. To claim, as I am to claim, that a description of its active chemical aspects must contribute to any adequate description of life is not to imply that a living organism is no more than a physico-chemical system. It implies that at a definite and recognisable level of its dynamic organisation an organism can be logically described in physico-chemical terms alone. At such a level indeed we may hope ultimately to arrive at a description which is complete in itself, just as descriptions at the morphological level of organisation may be complete in themselves. There may be yet higher levels calling for discussion in quite different terms.

I wish, however, to remind you of a mode of thought concerning the material basis of life, which though it prevailed when physico-chemical interpretations were fashionable, was yet almost as inhibitory to productive chemical thought and study as any of the claims of vitalism. This was the conception of that material basis as a single entity, as a definite though highly complex chemical compound. Up to the end of the last century and even later the term 'protoplasm' suggested such an entity to many minds. In his brilliant Presidential Address at the Association's meeting at Dundee twenty-two years ago, Sir Edward Sharpey-Schafer, after remarking that the elements composing living substances are few in number, went on to say: 'The combination of these elements into a colloid compound represents the physical basis of life, and when the chemist succeeds in building up this compound it will, without doubt, be found to exhibit the phenomena which we are in the habit of associating with the term "life"' Such a compound would seem to correspond with the 'protoplasm' of many biologists, though treated perhaps with too little respect. The Presidential claim might have seemed to encourage the biochemist, but the goal suggested would have proved elusive, and the path of endeavour has followed other lines.

So long as the term 'protoplasm' retains a morphological significance as in classical cytology, it may be even now convenient enough, though always denoting an abstraction. In so far, however, as the progress of metabolism with all the vital activities which it supports was ascribed in concrete thought to hypothetical qualities emergent from a protoplasmic complex in its integrity or when substances were held to suffer change only because in each living cell they are first built up, with loss of their own molecular structure and identity, in.o this complex, which is itself the inscrutable seat of cyclic change, then serious obscurantism was involved.

Had such assumptions been justified the old taunt that when the

chemist touches living matter it immediately becomes dead matter would also have been justified. A very distinguished organic chemist, long since dead, said to me in the late eighties: 'The chemistry of the living? That is the chemistry of protoplasm; that is superchemistry; seek, my young friend, for other ambitions.'

Research, however, during the present century, much of which has been done since the Association last met in Leicester, has yielded knowledge to justify the optimism of the few who started to work in those days. Were there time, I might illustrate this by abundant examples; but I think a single illustration will suffice to demonstrate how progress during recent years has changed the outlook for biochemistry. I will ask you to note the language used thirty years ago to describe the chemical events in active muscle and compare it with that used now. In 1895 Michael Foster, a physiologist of deep vision, dealing with the respiration of tissues, and in particular with the degree to which the activity of muscle depends on its contemporary oxygen supply, expounded the current view which may be thus briefly summarised. The oxygen which enters the muscle from the blood is not involved in immediate oxidations, but is built up into the substance of the muscle. It disappears into some protoplasmic complex on which its presence confers instability. This complex, which like all living substance, is to be regarded as incessantly undergoing changes of a double kind, those of building up and those of breaking down. With activity the latter predominates, and in the case of muscle the complex in question explodes, as it were, to yield the energy for contraction. 'We cannot yet trace,' Foster comments, 'the steps taken by the oxygen from the moment it slips from the blood into the muscle substance to the moment when it issues united with carbon as carbonic acid. The whole mystery of life lies hidden in that process, and for the present we must be content with simply knowing the beginning and the end.' What we feel entitled to say to-day concerning the respiration of muscle and of the events associated with its activity requires, as I have suggested, a different language, and for those not interested in technical chemical aspects the very change of language may yet be significant. The conception of continuous building up and continuous breakdown of the muscle substance as a whole, has but a small element of truth. The colloidal muscle structure is, so to speak, an apparatus, relatively stable even as a whole when metabolism is normal, and in essential parts very stable. The chemical reactions which occur in that apparatus have been followed with a completeness which is, I think, striking. It is carbohydrate stores distinct from the apparatus (and in certain circumstances also fat stores) which undergo steady oxidation and are the ultimate sources of energy for muscular work. Essential among successive stages in

the chemical breakdown of carbohydrate which necessarily precede oxidation is the intermediate combination of a sugar (a hexose) with phosphoric acid to form an ester. This happening is indispensable for the progress of the next stage, namely the production of lactic acid from the sugar, which is an anaerobic process. The precise happenings to the hexose sugar while in combination with phosphoric acid are from a chemical standpoint remarkable. Very briefly stated they are these. One half of the sugar molecule is converted into a molecule of glycerin and the other half into one of pyruvic acid. Now with loss of two hydrogen atoms glycerin yields lactic acid, and, with a gain of the same pyruvic acid also yields lactic acid. The actual happening then is that hydrogen is transferred from the glycerin molecule while still combined with phosphoric acid to the pyruvic acid molecule with the result that two molecules of lactic acid are formed.[1] The lactic acid is then, during a cycle of change which I must not stop to discuss, oxidised to yield the energy required by the muscle.

But the energy from this oxidation is by no means directly available for the mechanical act of contraction. The oxidation occurs indeed after and not before or during a contraction. The energy it liberates secures however the endothermic resynthesis of a substance, creatin phosphate, of which the breakdown at an earlier stage in the sequence of events is the more immediate source of energy for contraction. Even more complicated are these chemical relations, for it would seem that in the transference of energy from its source in the oxidation of carbohydrate to the system which synthesises creatin phosphate, yet another reaction intervenes, namely, the alternating breakdown and resynthesis of the substance adenyl pyrophosphate. The sequence of these chemical reactions in muscle has been followed and their relation in time to the phases of contraction and relaxation is established. The means by which energy is transferred from one reacting system to another has till lately been obscure, but current work is throwing light upon this interesting question, and it is just beginning (though only beginning) to show how at the final stage the energy of the reactions is converted into the mechanical response. In parenthesis it may be noted as an illustration of the unity of life that the processes which occur in the living yeast cell in its dealings with sugars are closely similar to those which proceed in living muscle. In the earlier stages they are identical and we now know where they part company. You will, I think, be astonished at the complexity of the events which underlie the activity of a muscle, but you must remember that it is a highly specialised machine. A more direct burning of the fuel could not fit into its complex organisation. I am more particularly concerned

[1] Lecture by Otto Meyerhof: in the Press (see *Nature*).

to feel that my brief summary of the facts will make you realise how much more definite, how much more truly chemical, is our present knowledge than that available when Michael Foster wrote. Ability to recognise the progress of such definite ordered chemical reactions in relation to various aspects of living activity characterises the current position in biochemistry. I have chosen the case of muscle, and it must serve as my only example, but many such related and ordered reactions have been studied in other cells and tissues, from bacteria to the brain. Some prove general, some more special. Although we are far indeed from possessing a complete picture in any one case we are beginning in thought to fit not a few pieces together. We are on a line safe for progress.

I must perforce limit the field of my discussion, and in what follows my special theme will be the importance of molecular structure in determining the properties of living systems. I wish you to believe that molecules display in such systems the properties inherent in their structure even as they do in the laboratory of the organic chemist. The theme is no new one, but its development illustrates as well as any other, and to my own mind perhaps better than any other, the progress of biochemistry. Not long ago a prominent biologist, believing in protoplasm as an entity, wrote: 'But it seems certain that living protoplasm is not an ordinary chemical compound, and therefore can have no molecular structure in the chemical sense of the word.' Such a belief was common. One may remark, moreover, that when the development of colloid chemistry first brought its indispensable aid towards an understanding of the biochemical field, there was a tendency to discuss its bearing in terms of the less specific properties of colloid systems, phase-surfaces, membranes, and the like, without sufficient reference to the specificity which the influence of molecular structure, whereever displayed, impresses on chemical relations and events. In emphasising its importance I shall leave no time for dealings with the nature of the colloid structures of cells and tissues, all important as they are. I shall continue to deal, though not again in detail, with chemical reactions as they occur within those structures. Only this much must be said. If the colloid structures did not display highly specialised molecular structure at their surface, no reactions would occur; for here catalysis occurs. Were it not equipped with catalysts every living unit would be a static system.

With the phenomena of catalysis I will assume you have general acquaintance. You know that a catalyst is an agent which plays only a temporary part in chemical events which it nevertheless determines and controls. It reappears unaltered when the events are completed. The phenomena of catalysis, though first recognised early in the last century, entered but little into chemical thought

or enterprise, till only a few years ago they were shown to have great importance for industry. Yet catalysis is one of the most significant devices of nature, since it has endowed living systems with their fundamental character as transformers of energy, and all evidence suggests that it must have played an indispensable part in the living universe from the earliest stages of evolution.

The catalysts of a living cell are the enzymic structures which display their influences at the surface of colloidal particles or at other surfaces within the cell. Current research continues to add to the great number of these enzymes which can be separated from, or recognised in, living cells and tissues, and to increase our knowledge of their individual functions.

A molecule within the system of the cell may remain in an inactive state and enter into no reactions until at one such surface it comes in contact with an enzymic structure which displays certain adjustments to its own structure. While in such association the inactive molecule becomes (to use a current term) ' activated,' and then enters on some definite path of change. The one aspect of enzymic catalysis which for the sake of my theme I wish to emphasise is its high specificity. An enzyme is in general adjusted to come into effective relations with one kind of molecule only, or at most with molecules closely related in their structure. Evidence based on kinetics justifies the belief that some sort of chemical combination between enzyme and related molecule precedes the activation of the latter, and for such combinations there must be close correlation in structure. Many will remember that long ago Emil Fischer recognised that enzymic action distinguishes even between two optical isomers and spoke of the necessary relation being as close as that of key and lock.

There is an important consequence of this high specificity in biological catalysis to which I will direct your special attention. A living cell is the seat of a multitude of reactions, and in order that it should retain in a given environment its individual identity as an organism, these reactions must be highly organised. They must be of determined nature and proceed mutually adjusted with respect to velocity, sequence, and in all other relations. They must be in dynamic equilibrium as a whole and must return to it after disturbance. Now if of any group of catalysts, such as are found in the equipment of a cell, each one exerts limited and highly-specific influence, this very specificity must be a potent factor in making for organisation.

Consider the case of any individual cell in due relations with its environment, whether an internal environment as in the case of the tissue cells of higher animals, or an external environment as in the case of unicellular organisms. Materials for maintenance of

the cell enter it from the environment. Discrimination among such materials is primarily determined by permeability relations, but of deeper significance in that selection is the specificity of the cell catalysts. It has often been said that the living cell differs from all non-living systems in its power of selecting from a heterogeneous environment the right material for the maintenance of its structure and activities. It is, however, no vital act but the nature of its specific catalysts which determines what it effectively ' selects.' If a molecule gains entry into the cell and meets no catalytic influence capable of activating it, nothing further happens save for certain ionic and osmotic adjustments. Any molecule which does meet an adjusted enzyme cannot fail to suffer change and become directed into some one of the paths of metabolism. It must here be remembered, moreover, that enzymes as specific catalysts not only promote reactions, but determine their direction. The glucose molecule, for example, though its inherent chemical potentialities are, of course, always the same, is converted into lactic acid by an enzyme system in muscle but into alcohol and carbon dioxide by another in the yeast cell. It is important to realise that diverse enzymes may act in succession and that specific catalysis has directive as well as selective powers. If it be syntheses in the cell which are most difficult to picture on such lines, we may remember that biological syntheses can be, and are, promoted by enzymes, and there are sufficient facts to justify the belief that a chain of specific enzymes can direct a complex synthesis along lines predetermined by the nature of the enzymes themselves. I should like to develop this aspect of the subject even further, but to do so might tax your patience. I should add that enzyme-control, though so important, is not the sole determinant of chemical organisation in a cell. Other aspects of its colloidal structure play their part.

III.

It is surely at that level of organisation, which is based on the exact co-ordination of a multitude of chemical events within it, that a living cell displays its peculiar sensitiveness to the influence of molecules of special nature when these enter it from without. The nature of very many organic molecules is such that they may enter a cell and exert no effect. Those proper to metabolism follow, of course, the normal paths of change. Some few, on the other hand, influence the cell in very special ways. When such influence is highly specific in kind it means that some element of structure in the entrant molecule is adjusted to meet an aspect of molecular structure somewhere in the cell itself. We can easily understand that in a system so minute the intrusion even of a few such molecules

may so modify existing equilibria as to affect profoundly the observed behaviour of the cell.

Such relations, though by no means confined to them, reach their greatest significance in the higher organisms, in which individual tissues, chemically diverse, differentiated in function and separated in space, so react upon one another through chemical agencies transmitted through the circulation as to co-ordinate by chemical transport the activities of the body as a whole. Unification by chemical means must to-day be recognised as a fundamental aspect of all such organisms. In all of them it is true that the nervous system has pride of place as the highest seat of organising influence, but we know to-day that even this influence is often, if not always, exerted through properties inherent in chemical molecules. It is indeed most significant for my general theme to realise that when a nerve impulse reaches a tissue the sudden production of a definite chemical substance at the nerve ending may be essential to the response of that tissue to the impulse. It is a familiar circumstance that when an impulse passes to the heart by way of the vagus nerve fibres the beat is slowed, or, by a stronger beat, arrested. That is, of course, part of the normal control of the heart's action. Now it has been shown that whenever the heart receives vagus impulses the substance acetyl cholin is liberated within the organ. To this fact is added the further fact that, in the absence of the vagus influence, the artificial injection of minute graded doses of acetyl choline so acts upon the heart as to reproduce in every detail the effects of graded stimulation of the nerve. Moreover, evidence is accumulating to show that in the case of other nerves belonging to the same morphological group as the vagus, but supplying other tissues, this same liberation of acetyl choline accompanies activity, and the chemical action of this substance upon such tissues again produces effects identical with those observed when the nerves are stimulated. More may be claimed. The functions of another group of nerves are opposed to those of the vagus group ; impulses, for instance, through certain fibres accelerate the heart beat. Again a chemical substance is liberated at the endings of such nerves, and this substance has itself the property of accelerating the heart. We find then that such organs and tissues respond only indirectly to whatever non-specific physical change may reach the nerve ending. Their direct response is to the influence of particular molecules with an essential structure when these intrude into their chemical machinery.

It follows that the effect of a given nerve stimulus may not be confined to the tissue which it first reaches. There may be humeral transmissions of its effect, because the liberated substance enters the lymph and blood. This again may assist the co-ordination of events in the tissues.

From substances produced temporarily and locally and by virtue of their chemical properties translating for the tissues the messages of nerves, we may pass logically to consideration of those active substances which carry chemical messages from organ to organ. Such in the animal body are produced continuously in specialised organs, and each has its special seat or seats of action where it finds chemical structures adjusted in some sense or other to its own.

I shall be here on familiar ground, for that such agencies exist, and bear the name of hormones, is common knowledge. I propose only to indicate how many and diverse are their fuctions as revealed by recent research, emphasising the fact that each one is a definite and relatively simple substance with properties that are primarily chemical and in a derivate sense physiological. Our clear recognition of this, based at first on a couple of instances, began with this century, but our knowledge of their number and nature is still growing rapidly to-day.

We have long known, of course, how essential and profound is the influence of the thyroid gland in maintaining harmonious growth in the body, and in controlling the rate of its metabolism. Three years ago a brilliant investigation revealed the exact molecular structure of the substance—thyroxin—which is directly responsible for these effects. It is a substance of no great complexity. The constitution of adrenalin has been longer known and likewise its remarkable influence in maintaining a number of important physiological adjustments. Yet is is again a relatively simple substance. I will merely remind you of secretin, the first of these substances to receive the name of hormone, and of insulin, now so familiar because of its importance in the metabolism of carbohydrates and its consequent value in the treatment of diabetes. The most recent growth of knowledge in this field has dealt with hormones which, in most remarkable relations, co-ordinate the phenomena of sex.

It is the circulation of definite chemical substances produced locally that determines during the growth of the individual, the proper development of all the secondary sexual characters. The properties of other substances secure the due progress of individual development from the unfertilised ovum to the end of fœtal life. When an ovum ripens and is discharged from the ovary a substance, now known as œstrin, is produced in the ovary itself, and so functions as to bring about all those changes in the female body which make secure the fertilisation of the ovum. On the discharge of the ovum new tissue, constituting the so-called *corpus luteum*, arises in its place. This then produces a special hormone which in its turn evokes all those changes in tissues and organs that secure a right destiny for the ovum after it has been fertilised. It is clear that

these two hormones do not arise simultaneously, for they must act in alternation, and it becomes of great interest to know how such succession is secured. The facts here are among the most striking. Just as higher nerve centres in the brain control and co-ordinate the activities of lower centres, so it would seem do hormones, functioning at, so to speak, a higher level in organisation, co-ordinate the activities of other hormones. It is a substance produced in the anterior portion of the pituitary gland situated at the base of the brain, which by circulating to the ovary controls the succession of its hormonal activities. The cases I have mentioned are far from exhausting the numerous hormonal influences now recognised.

For full appreciation of the extent to which chemical substances control and co-ordinate events in the animal body by virtue of their specific molecular structure, it is well not to separate too widely in thought the functions of hormones from those of vitamins. Together they form a large group of substances of which every one exerts upon physiological events its own indispensable chemical influence.

Hormones are produced in the body itself, while vitamins must be supplied in the diet. Such a distinction is, in general, justified. We meet occasionally, however, an animal species able to dispense with an external supply of this or that vitamin. Evidence shows, however, that individuals of that species, unlike most animals, can in the course of their metabolism synthesise for themselves the vitamin in question. The vitamin then becomes a hormone. In practice the distinction may be of great importance, but for an understanding of metabolism the functions of these substances are of more significance than their origin.

The present activity of research in the field of vitamins is prodigious. The output of published papers dealing with original investigations in the field has reached nearly a thousand in a single year. Each of the vitamins at present known is receiving the attention of numerous observers in respect both of its chemical and biological properties, and though many publications deal, of course, with matters of detail, the accumulation of significant facts is growing fast.

It is clear that I can cover but little ground in any reference to this wide field of knowledge. Some aspects of its development have been interesting enough. The familiar circumstance that attention was drawn to the existence of one vitamin (B_1 so called) because populations in the East took to eating milled rice instead of the whole grain; the gradual growth of evidence which links the physiological activities of another vitamin (D) with the influence of solar radiation on the body, and has shown that they are thus related, because rays of definite wave-length convert an inactive precurser into the active vitamin, alike when acting on foodstuffs

or on the surface of the living body ; the fact again that the recent isolation of vitamin C, and the accumulation of evidence for its nature started from the observation that the cortex of the adrenal gland displayed strongly reducing properties ; or yet again the proof that a yellow pigment widely distributed among plants, while not the vitamin itself, can be converted within the body into vitamin A ; these and other aspects of vitamin studies will stand out as interesting chapters in the story of scientific investigation.

In this very brief discussion of hormones and vitamins I have so far referred only to their functions as manifested in the animal body. Kindred substances, exerting analogous functions, are, however, of wide and perhaps of quite general biological importance. It is certain that many micro-organisms require a supply of vitamin-like substances for the promotion of growth, and recent research of a very interesting kind has demonstrated in the higher plants the existence of specific substances produced in special cells which stimulate growth in other cells, and so in the plant as a whole. These so-called auxines are essentially hormones. Section B will soon be listening to an account of their chemical nature.

It is of particular importance to my present theme and a source of much satisfaction to know that our knowledge of the actual molecular structure of hormones and vitamins is growing fast. We have already exact knowledge of the kind in respect to not a few. We are indeed justified in believing that within a few years such knowledge will be extensive enough to allow a wide view of the correlation between molecular structure and physiological activity. Such correlation has long been sought in the case of drugs, and some generalisations have been demonstrated. It should be remembered, however, that until quite lately only the structure of the drug could be considered. With increasing knowledge of the tissue structures pharmacological actions will become much clearer.

I cannot refrain from mentioning here a set of relations connected especially with the phenomena of tissue growth which are of particular interest. It will be convenient to introduce some technical chemical considerations in describing them, though I think the relations may be clear without emphasis being placed on such details. The vitamin, which in current usage is labelled ' A,' is essential for the general growth of an animal. Recent research has provided much information as to its chemical nature. Its molecule is built up of units which possess what is known to chemists as the isoprene structure. These are condensed in a long carbon chain which is attached to a ring structure of a specific kind. Such a constitution relates it to other biological compounds, in particular to certain vegetable pigments, one of which a carotene, so called, is the substance which I have mentioned as being convertible into the

vitamin. For the display of an influence upon growth, however, the exact details of the vitamin's proper structure must be established. Now turning to vitamin D, of which the activity is more specialised, controlling as it does the growth of bone in particular, we have learnt that the unit elements in its structure are again isoprene radicals; but instead of forming a long chain as in vitamin A they are united into a system of condensed rings. Similar rings form the basal component of the molecules of sterols, substances which are normal constituents of nearly every living cell. It is one of these, inactive itself, which ultra-violet radiation converts into vitamin D. We know that as stated each of these vitamins stimulates growth in tissue cells. Next consider another case of growth stimulation, different because pathological in nature. As you are doubtless aware, it is well known that long contact with tar induces a cancerous growth of the skin. Very important researches have recently shown that particular constituents in the tar are alone concerned in producing this effect. It is being further demonstrated that the power to produce cancer is associated with a special type of molecular structure in these constituents. This structure, like that of the sterols, is one of condensed rings, the essential difference being that (in chemical language) the sterol rings are hydrogenated, whereas those in the cancer-producing molecules are not. Hydrogenation indeed destroys the activity of the latter. Recall, however, the ovarian hormone œstrin. Now the molecular structure of œstrin has the essential ring structure of a sterol, but one of the constituent rings is not hydrogenated. In a sense therefore the chemical nature of œstrin links vitamin D with that of cancer-producing substances. Further, it is found that substances with pronounced cancer-producing powers may produce effects in the body like those of œstrin. It is difficult when faced with such relations not to wonder whether the metabolism of sterols, which when normal can produce a substance stimulating physiological growth, may in very special circumstances be so perverted as to produce within living cells a substance stimulating pathological growth. Such a suggestion must, however, with present knowledge, be very cautiously received. It is wholly without experimental proof. My chief purpose in this reference to this very interesting set of relations is to emphasise once more the significance of chemical structure in the field of biological events.

Only the end results of the profound influence which minute amounts of substances with adjusted structure exert upon living cells or tissues can be observed in the intact bodies of man or animals. It is doubtless because of the elaborate and sensitive organisation of chemical events in every tissue cell that the effects are proportionally so great.

It is an immediate task of biochemistry to explore the mechanism

of such activities. It must learn to describe in objective chemical terms precisely how and where such molecules as those of hormones and vitamins intrude into the chemical events of metabolism. It is indeed now beginning this task which is by no means outside the scope of its methods. Efforts of this and of similar kind cannot fail to be associated with a steady increase in knowledge of the whole field of chemical organisation in living organisms, and to this increase we look forward with confidence. The promise is there. Present methods can still go far, but I am convinced that progress of the kind is about to gain great impetus from the application of those new methods of research which chemistry is inheriting from physics: X-ray analysis; the current studies of unimolecular surface films and of chemical reactions at surfaces; modern spectroscopy; the quantitative developments of photo-chemistry; no branch of inquiry stands to gain more from such advances in technique than does biochemistry at its present stage. Especially is this true in the case of the colloidal structure of living systems, of which in this Address I have said so little.

IV.

As an experimental science, biochemistry, like classical physiology, and much of experimental biology, has obtained, and must continue to obtain, many of its data from studying parts of the organism in isolation, but parts in which dynamic events continue. Though fortunately it has also methods of studying reactions as they occur in intact living cells, intact tissues, and, of course, in the intact animal, it is still entitled to claim that its studies of parts are consistently developing its grasp of the Wholes it desires to describe, however remote that grasp may be from finality. Justification for any such claim has been challenged in advance from a certain philosophic standpoint. Not from that of General Smuts, though in his powerful Address which signalised our centenary meeting he, like many philosophers to-day, emphasised the importance of properties which emerge from systems in their integrity, bidding us remember that a part while in the whole is not the same as the part in isolation. He hastened to admit in a subsequent speech, however, that for experimental biology, as for any other branch of science, it was logical and necessary to approach the whole through its parts. Nor again is the claim challenged from the standpoint of such a teacher as A. N. Whitehead, though in his philosophy of organic mechanism there is no real entity of any kind without internal and multiple relations, and each whole is more than the sum of its parts. I nevertheless find *ad hoc* statements in his writings which directly encourage the methods of biochemistry. In the teachings of J. S. Haldane, however, the value of such methods have long been directly

challenged. Some here will perhaps remember that in his Address to Section I, twenty-five years ago he described a philosophic standpoint which he has courageously maintained in many writings since. Dr. Haldane holds that to the enlightened biologist a living organism does not present a problem for analysis ; it is, *qua* organism, axiomatic. Its essential attributes are axiomatic; heredity, for example, is for biology not a problem but an axiom. 'The problem of Physiology is not to obtain piecemeal physico-explanations of physiological processes' (I quote from the 1885 Address), 'but to discover by observation and experiment the relatedness to one another of all the details of structure and activity in each organism as expressions of its nature as one organism.' I cannot pretend adequately to discuss these views here. They have often been discussed by others, not always perhaps with understanding. What is true in them is subtle, and I doubt if their author has ever found the right words in which to bring to most others a conviction of such truth. It is involved in a world outlook. What I think is scientifically faulty in Haldane's teaching is the *a priori* element which leads to bias in the face of evidence. The task he sets for the physiologist seems vague to most people, and he forgets that with good judgment a study of parts may lead to an intellectual synthesis of value. In 1885 he wrote : 'That a meeting-point between Biology and Physical Science may at some time be found there is no reason for doubting. But we may confidently predict that if that meeting-point is found, and one of the two sciences is swallowed up, that one will not be Biology.' He now claims indeed that biology has accomplished the heavy meal because physics has been compelled to deal no longer with Newtonian entities but, like the biologist, with organisms such as the atom proves to be. Is it not then enough for my present purpose to remark on the significance of the fact that not until certain atoms were found spontaneously splitting piecemeal into parts, and others were afterwards so split in the laboratory, did we really know anything about the atom as a whole.

At this point, however, I will ask you not to suspect me of claiming that all the attributes of living systems or even the more obvious among them are necessarily based upon chemical organisation alone. I have already expressed my own belief that this organisation will account for one striking characteristic of every living cell—its ability, namely, to maintain a dynamic individuality in diverse environments. Living cells display other attributes even more characteristic of themselves ; they grow, multiply, inherit qualities and transmit them. Although to distinguish levels of organisation in such systems may be to abstract from reality it is not illogical to believe that such attributes as these are based upon organisation at a level

which is in some sense higher than the chemical level. The main necessity from the standpoint of biochemistry is then to decide whether nevertheless at its own level, which is certainly definable, the results of experimental studies are self-contained and consistent. This is assuredly true of the data which biochemistry is now acquiring. Never during its progress has chemical consistency shown itself to be disturbed by influences of any ultra-chemical kind.

Moreover, before we assume that there is a level of organisation at which chemical controlling agencies must necessarily cease to function, we should respect the intellectual parsimony taught by Occam and be sure of their limitations before we seek for superchemical entities as organisers. There is no orderly succession of events which would seem less likely to be controlled by the mere chemical properties of a substance than the cell divisions and cell differentiation which intervene between the fertilised ovum and the finished embryo. Yet it would seem that a transmitted substance, a hormone in essence, may play an unmistakable part in that remarkable drama. It has for some years been known that, at an early stage of development, a group of cells forming the so-called ‘ organiser ’ of Spemann induces the subsequent stages of differentiation in other cells. The latest researches seem to show that a cell-free extract of this ‘ organiser ’ may function in its place. The substance concerned is, it would seem, not confined to the ‘ organiser ’ itself, but is widely distributed outside, though not in, the embryo. It presents, nevertheless, a truly remarkable instance of chemical influence.

It would be out of place in such a discourse as this to attempt any discussion of the psycho-physical problem. However much we may learn about the material systems which, in their integrity, are associated with consciousness, the nature of that association may yet remain a problem. The interest of that problem is insistent and it must be often in our thoughts. Its existence, however, justifies no pre-judgments as to the value of any knowledge of a consistent sort which the material systems may yield to experiment.

V.

It has become clear, I think, that chemical modes of thought, whatever their limitation, are fated profoundly to affect biological thought. If, however, the biochemist should at any time be inclined to overrate the value of his contributions to biology, or to underrate the magnitude of problems outside his province, he will do well sometimes to leave the laboratory for the field, or to seek even in the museum a reminder of that infinity of adaptations of which life is capable. He will then not fail to work with a humble mind, however great his faith in the importance of the methods which are his own.

It is surely right, however, to claim that in passing from its earlier concern with dead biological products to its present concern with active processes within living organisms, biochemistry has become a true branch of progressive biology. It has opened up modes of thought about the physical basis of life which could scarcely be employed at all a generation ago. Such data and such modes of thought as it is now providing are pervasive, and must appear as aspects in all biological thought. Yet these aspects are, of course, only partial. Biology in all its aspects is showing rapid progress, and its bearing on human welfare is more and more evident.

Unfortunately the nature of this new biological progress and its true significance is known to but a small section of the lay public. Few will doubt that popular interest in science is extending, but it is mainly confined to the more romantic aspects of modern astronomy and physics. That biological advances have made less impression is probably due to more than one circumstance, of which the chief, doubtless, is the neglect of biology in our educational system. The startling data of modern astronomy and physics, though of course only when presented in their most superficial aspects, find an easier approach to the uninformed mind than those of the new experimental biology can hope for. The primary concepts involved are paradoxically less familiar. Modern physical science, moreover, has been interpreted to the intelligent public by writers so brilliant that their books have had a great and stimulating influence.

Lord Russell once ventured on the statement that in passing from physics to biology one is conscious of a transition from the cosmic to the parochial, because from a cosmic point of view life is a very unimportant affair. Those who know that supposed parish well are convinced that it is rather a metropolis entitled to much more attention than it sometimes obtains from authors of guide-books to the universe. It may be small in extent, but is the seat of all the most significant events. In too many current publications, purporting to summarise scientific progress, biology is left out or receives but scant reference. Brilliant expositions of all that may be met in the region where modern science touches philosophy have directed thought straight from the implications of modern physics to the nature and structure of the human mind, and even to speculation concerning the mind of the Deity. Yet there are aspects of biological truth already known which are certainly germane to such discussions, and probably necessary for their adequacy.

VI.

It is, however, because of its extreme importance to social progress that public ignorance of biology is especially to be regretted. Sir Henry Dale has remarked that 'it is worth while to consider

to-day whether the imposing achievements of physical science have not already, in the thought and interests of men at large, as well as in technical and industrial development, overshadowed in our educational and public policy those of biology to an extent which threatens a one-sided development of science itself and of the civilisation which we hope to see based on science.' Sir Walter Fletcher, whose death during the past year has deprived the nation of an enlightened adviser, almost startled the public, I think, when he said in a national broadcast that ' we can find safety and progress only in proportion as we bring into our methods of statecraft the guidance of biological truth.' That statecraft, in its dignity, should be concerned with biological teaching, was a new idea to many listeners. A few years ago the Cambridge philosopher, Dr. C. D. Broad, who is much better acquainted with scientific data than are many philosophers, remarked upon the misfortune involved in the unequal development of science ; the high degree of our control over inorganic nature combined with relative ignorance of biology and psychology. At the close of a discussion as to the possibility of continued mental progress in the world, he summed up by saying that the possibility depends on our getting an adequate knowledge and control of life and mind before the combination of ignorance on these subjects with knowledge of physics and chemistry wrecks the whole social system. He closed with the somewhat startling words : ' Which of the runners in this very interesting race will win it is impossible to foretell. But physics and death have a long start over psychology and life ! ' No one surely will wish for, or expect, a slowing in the pace of the first, but the quickening up in the latter which the last few decades have seen is a matter for high satisfaction. But, to repeat, the need for recognising biological truth as a necessary guide to individual conduct and no less to statecraft and social policy still needs emphasis to-day. With frank acceptance of the truth that his own nature is congruent with all those aspects of nature at large which biology studies, combined with intelligent understanding of its teaching, man would escape from innumerable inhibitions due to past history and present ignorance, and equip himself for higher levels of endeavour and success.

Inadequate as at first sight it may seem when standing alone in support of so large a thesis, I must here be content to refer briefly to a single example of biological studies bearing upon human welfare. I will choose one which stands near to the general theme of my address. I mean the current studies of human and animal nutrition. You are well aware that during the last twenty years—that is, since it adopted the method of controlled experiment—the study of nutrition has shown that the needs of the body are much more complex than was earlier thought, and in particular that

substances consumed in almost infinitesimal amounts may, each in its way, be as essential as those which form the bulk of any adequate dietary. This complexity in its demands will, after all, not surprise those who have in mind the complexity of events in the diverse living tissues of the body.

My earlier reference to vitamins, which had somewhat different bearings, was, I am sure, not necessary for a reminder of their nutritional importance. Owing to abundance of all kinds of advertisement vitamins are discussed in the drawing-room as well as in the dining-room, and also, though not so much, in the nursery, while at present perhaps not enough in the kitchen. Unfortunately, among the uninformed their importance in nutrition is not always viewed with discrimination. Some seem to think nowadays that if the vitamin supply is secured the rest of the dietary may be left to chance, while others suppose that they are things so good that we cannot have too much of them. Needless to say, neither assumption is true. With regard to the second indeed it is desirable, now that vitamin concentrates are on the market and much advertised, to remember that excess of a vitamin may be harmful. In the case of that labelled D at least we have definite evidence of this. Nevertheless the claim that every known vitamin has highly important nutritional functions is supported by evidence which continues to grow. It is probable, but perhaps not yet certain, that the human body requires all that are known.

The importance of detail is no less in evidence when the demands of the body for a right mineral supply are considered. A proper balance among the salts which are consumed in quantity is here of prime importance, but that certain elements which ordinary foods contain in minute amounts are indispensable in such amounts is becoming sure. To take but a single instance : the necessity of a trace of copper, which exercises somewhere in the body an indispensable catalytic influence on metabolism, is as essential in its way as much larger supplies of calcium, magnesium, potassium or iron. Those in close touch with experimental studies continually receive hints that factors still unknown contribute to normal nutrition, and those who deal with human dietaries from a scientific standpoint know that an ideal diet cannot yet be defined. This reference to nutritional studies is indeed mainly meant to assure you that the great attention they are receiving is fully justified. No one here, I think, will be impressed with the argument that because the human race has survived till now in complete ignorance of all such details the knowledge being won must have academic interest alone. This line of argument is very old and never right.

One thing I am sure may be claimed for the growing enlightenment concerning human nutrition and the recent recognition of its

study. It has already produced one line of evidence to show that Nurture can assist Nature to an extent not freely admitted a few years ago. That is a subject which I wish I could pursue. I cannot myself doubt that various lines of evidence, all of which should be profoundly welcome, are pointing in the same direction.

Allow me just one final reference to another field of nutritional studies. Their great economic importance in animal husbandry calls for full recognition. Just now agricultural authorities are becoming acutely aware of the call for a better control of the diseases of animals. Together these involve an immense economic loss to the farmers, and therefore to the country. Although, doubtless, its influence should not be exaggerated, faulty nutrition plays no small share in accounting for the incidence of some among these diseases, as researches carried out at the Rowett Institute in Aberdeen and elsewhere are demonstrating. There is much more of such work to be done with great profit.

VII.

In every branch of science the activity of research has greatly increased during recent years. This all will have realised, but only those who are able to survey the situation closely can estimate the extent of that increase. It occurred to me at one time that an appraisement of research activities in this country, and especially the organisation of State-aided research, might fittingly form a part of my address. The desire to illustrate the progress of my own subject led me away from that project. I gave some time to a survey however, and came to the conclusion, among others, that from eight to ten individuals in the world are now engaged upon scientific investigations for every one so engaged twenty years ago. It must be remembered, of course, that not only has research endowment greatly increased in America and Europe, but that Japan, China, and even India have entered the field and are making contributions to science of real importance. It is sure that, whatever the consequences, the increase of scientific knowledge is at this time undergoing a positive acceleration.

Apropos, I find difficulty as to-day's occupant of this important scientific pulpit in avoiding some reference to impressive words spoken by my predecessor which are still echoed in thought, talk and print. In his wise and eloquent address at York Sir Alfred Ewing reminded us with serious emphasis that the command of Nature has been put into man's hand before he knows how to command himself. Of the dangers involved in that indictment he warned us; and we should remember that General Smuts also sounded the same note of warning in London.

Of Science itself it is, of course, no indictment. It may be thought

of rather as a warning signal to be placed on her road : ‘ Dangerous Hill Ahead,’ perhaps, or ‘ Turn Right ’ ; not, however, ‘ Go Slow,’ for that advice Science cannot follow. The indictment is of mankind. Recognition of the truth it contains cannot be absent from the minds of those whose labours are daily increasing mankind’s command of Nature ; but it is due to them that the truth should be viewed in proper perspective. It is, after all, war, to which Science has added terrors, and the fear of war, which alone give it real urgency ; an urgency which must of course be felt in these days when some nations at least are showing the spirit of selfish and dangerous nationalism. I may be wrong but it seems to me that, war apart, the gifts of science and invention have done little to increase opportunities for the display of the more serious of man’s irrational impulses. The worst they do perhaps is to give to clever and predatory souls that keep within the law, the whole world for their depredations, instead of a parish or a country as of yore.

But Sir Alfred Ewing told us of ‘ the disillusion with which, now standing aside, he watches the sweeping pageant of discovery and invention in which he used to make unbounded delight.’ I wish that one to whom applied science and this country owe so much might have been spared such disillusion, for I suspect it gives him pain. I wonder whether, if he could have added to an ‘ Engineer’s Outlook ’ the outlook of a biologist, the disillusion would still be there. As one just now advocating the claims of biology I would much like to know. It is sure, however, that the gifts of the engineer to humanity at large are immense enough to outweigh the assistance he may have given to the forces of destruction.

It may be claimed for biological science, in spite of vague references to bacterial warfare and the like, that it is not of its nature to aid destruction. What it may do towards making man as a whole more worthy of his inheritance has yet to be fully recognised. On this point I have said much. Of its service to his physical betterment you will have no doubts. I have made but the bare reference in this address to the support that biological research gives to the art of medicine. I had thought to say much more of this, but found that if I said enough I could say nothing else.

There are two other great questions so much to the front just now that they tempt a final reference. I mean, of course, the paradox of poverty amidst plenty and the replacement of human labour by machinery. Applied science should take no blame for the former, but indeed claim credit unfairly lost. It is not within my capacity to say anything of value about the paradox and its cure ; but I confess that I see more present danger in the case of ‘ Money versus Man ’ than danger present or future in that of the ‘ Machine versus Man ’ !

With regard to the latter it is surely right that those in touch with science should insist that the replacement of human labour will continue. Those who doubt this cannot realise the meaning of that positive acceleration in science, pure and applied, which now continues. No one can say what kind of equilibrium the distribution of leisure is fated to reach. In any case an optimistic view as to the probable effects of its increase may be justified.

It need not involve a revolutionary change if there is real planning for the future. Lord Melchett was surely right when some time ago he urged on the upper House that present thought should be given to that future; but I think few men of affairs seriously believe what is yet probable, that the replacement we are thinking of will impose a new structure upon society. This may well differ in some essentials from any of those alternative social forms of which the very names now raise antagonisms. I confess that if civilisation escapes its other perils I should fear little the final reign of the machine. We should not altogether forget the difference in use which can be made of real and ample leisure compared with that possible for very brief leisure associated with fatigue; nor the difference between compulsory toil and spontaneous work. We have to picture, moreover, the reactions of a community which, save for a minority, has shown itself during recent years to be educable. I do not think it fanciful to believe that our highly efficient national broadcasting service, with the increased opportunities which the coming of short wave-length transmission may provide, might well take charge of the systematic education of adolescents after the personal influence of the schoolmaster has prepared them to profit by it. It would not be a technical education but an education for leisure. Listening to organised courses of instruction might at first be for the few; but ultimately might become habitual in the community which it would specially benefit.

In parenthesis allow me a brief further reference to 'planning.' The word is much to the front just now, chiefly in relation with current enterprises. But there may be planning for more fundamental developments; for future adjustment to social reconstructions. In such planning the trained scientific mind must play its part. Its vision of the future may be very limited, but in respect of material progress and its probable consequences Science (I include all branches of knowledge to which the name applies) has at least better data for prophecy than other forms of knowledge.

It was long ago written, 'Wisdom and Knowledge shall be stability of Thy times.' Though statesmen may have wisdom adequate for the immediate and urgent problems with which it is their fate to deal, there should yet be a reservoir of synthesised and clarified knowledge on which they can draw. The technique which

brings Governments in contact with scientific knowledge in particular, though greatly improved of late, is still imperfect. In any case the politician is perforce concerned with the present rather than the future. I have recently read Bacon's *New Atlantis* afresh and have been thinking about his Solomon's House. We know that the rules for the functioning of that House were mistaken because the philosopher drew them up when in the mood of a Lord Chancellor ; but in so far as the philosopher visualised therein an organisation of the best intellects bent on gathering knowledge for future practical services, his idea was a great one. When civilisation is in danger and society in transition might there not be a House recruited from the best intellects in the country with functions similar (*mutatis mutandis*) to those of Bacon's fancy ? A House devoid of politics, concerned rather with synthesising existing knowledge, with a sustained appraisement of the progress of knowledge, and continuous concern with its bearing upon social readjustments. It is not to be pictured as composed of scientific authorities alone. It would be rather an intellectual exchange where thought would go ahead of immediate problems. I believe, perhaps foolishly, that given time I might convince you that the functions of such a House, in such days as ours, might well be real. Here I must leave them to your fancy, well aware that in the minds of many I may by this bare suggestion lose all reputation as a realist !

I will now hasten to my final words. Most of us have had a tendency in the past to fear the gift of leisure to the majority. To believe that it may be a great social benefit requires some mental adjustment, and a belief in the educability of the average man or woman.

But if the political aspirations of the nations should grow sane, and the artificial economic problems of the world be solved, the combined and assured gifts of health, plenty, and leisure may prove to be the final justification of applied science. In a community advantaged by these each individual will be free to develop his own innate powers, and, becoming more of an individual, will be less moved by those herd instincts which are always the major danger to the world.

You may feel that throughout this address I have dwelt exclusively on the material benefits of science to the neglect of its cultural value. I would like to correct this in a single closing sentence. I believe that for those who cultivate it in a right and humble spirit, Science is one of the Humanities ; no less.

SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCES.

SEASONAL WEATHER AND ITS PREDICTION

ADDRESS BY

PROF. SIR GILBERT T. WALKER, C.S.I., F.R.S.,

PRESIDENT OF THE SECTION.

I HAVE chosen the subject of seasonal weather for my address, because its economic importance is obvious to most men who have lived in the Tropics, and its scientific problems are full of interest. Unfortunately there is an additional motive, the need of warning against dangers ahead. For the difficulties of long-range forecasting are not in general adequately recognised, so that some of the most progressive countries in the world are inclined to make predictions on an insecure basis; their technical staff does not realise that though the prestige of meteorology may be raised for a few years by the issue of seasonal forecasts, the harm done to the science will inevitably outweigh the good if the prophecies are found unreliable. We only learn from experience that while the forecasting efforts of a charlatan are judged by their occasional successes, it is the occasional failures of a government department which are remembered against it.

In a country where conditions are as changeable from day to day as they are here, it is natural that we should think in terms of wet or fine days rather than of wet or dry periods; but in the greater part of our empire the different seasons are much more sharply defined, and so their dominant features stand out more clearly. Also the variability of their seasons is in general materially greater than here. Thus in the annual rainfall measurements of the last half-century the smallest rainfall of Great Britain has been 23 per cent. below normal; but that of large areas in South Africa has been in defect by 40 per cent., in north-east Australia by 50 per cent., and in the Punjab by as much as 58 per cent., or two and a half times that of this country.

Now a season that is unusual seems to have some abnormal factor permanently at work diverting the weather from its ordinary course; in India I found, when issuing the daily forecast in a dry winter, that I had at times to predict no rain, when with identical conditions as shown by the weather map I should in a wet winter have predicted a widespread fall. Even in England, in winter, there is an appreciable persistence in the characteristics: during the last sixty years the fifteen wettest Januaries were followed by Februaries of more than average rainfall in

ten cases; and with dry Januaries also there is a similar two-to-one chance of a prolongation of the character. It is this persistence, especially when it is preceded by abnormal features in other regions, that seems now to hold out most promise of reliability in forecasting. In agricultural countries in which a failure of the rains involves a national calamity, the desirability of making preparations in advance has long ago led to efforts at prediction; and the demand has been so great that the supply has been forthcoming before its quality would bear the most cursory examination. The causes of unusual weather seem hopelessly obscure to the layman; and hence primitive ideas, surviving in the depth of our natures from countless ages of magical practices, still come to the surface in connection with it. In India I have been officially asked what is the need of an expensive and difficult scientific inquiry into the causes of drought when Hindu astrology will indicate what is coming; and many a country that claims to be dominated by Western science fails to recognise that events in weather obey the ordinary laws of physics and chemistry. The almost universal idea that weather must repeat itself after a certain number of years finds its origin, I believe, ultimately in the ancient belief in the control of our affairs by the heavenly bodies with their definite cycles—a belief which clearly shows itself in the supposed influence of the moon on the weather. Be that as it may, the faith in periods is so deep-seated that even in scientific discussions the ordinary tests for validity are very often ignored: more than once I have seen in journals of repute the artless remark of an author that if he were to limit his results to those which would satisfy the criteria of reality he would obtain few results of interest!

Another regrettable feature of current practice, even in important memoirs, is that of classing together processes with true periods and those sometimes called 'quasi-periodic,' of which the period varies. If our ideas are to be applied with success in the present enterprise their currency must be stabilised, and no good can come of attempting to pass off a vague surge of a few years as a three-year period.

After these preliminary remarks I propose to make a rapid sketch of the relationships that have been found between seasonal features in different parts of the world, then to describe the efforts that have actually been made to issue long-range forecasts, and finally to consider the directions from which improvements can be hoped for.

In the collection of World Weather Records, of which the publication was made possible by American generosity six years ago, there are about a thousand series of monthly data of pressure, temperature and rainfall; and these form but a scanty network. If quarterly values were computed and correlation coefficients between each pair for contemporary seasons, as well as for seasons one quarter before and after, we should have about four million coefficients. Co-ordination and generalisation are imperatively called for, and the development of the subject lies in the discovery of regions over which the variations are linked together.

After preliminary efforts by Buchan, Hoffmeyer, Blanford, de Bort, Hann, Meinardus and Pettersson, the far-reaching possibilities were first visualised by Hildebrandsson, who plotted pressure curves for ten

years of sixty-eight stations scattered over the world and drew attention to the relations between them: among these the opposition between Sydney in Australia and Buenos Aires was fated to have great influence: his subsequent studies involved temperature and rainfall also. In 1902 the Lockyers confirmed the existence of the see-saw between pressure in the Argentine and in India or Australia; and using graphical methods produced a world map, dividing areas in it according as their pressures varied with India or South America. They were followed by Bigelow's study of relationships with solar prominences. During recent years considerable development has followed the introduction of statistical methods, particularly in the hands of Exner, and of members of the meteorological services of England and India.

It will be convenient if I may here introduce a technical phrase. If we have two series of numbers of which the variations are connected, there will be a certain proportion of the variations of each which are associated with those of the other, and this proportion is called the correlation coefficient between the series. If it is nearly unity the numbers vary closely together; if it is small there is little relationship between them; and if it approaches -1 the relationship is close, but one series goes up when the other goes down.

Let us now consider some of the results of the analysis of seasonal features. It has long been known that in the North Atlantic Ocean there are two types of winter. In one pressure is high near the Azores and south-west Europe, and low in Iceland, while temperatures are high in north-west Europe; in the other type all these features are reversed. (See the three upper graphs in Fig. 1.) Let us suppose that we want to know the effect of these types on, say, temperature in Labrador. An obvious plan would be to plot the variations in successive winters, December to February, of the quantities which increase together, such as Vienna pressure and Stornoway temperature, and also of the quantities which decrease when the former increase, such as Iceland pressure, reversing these so as to secure similarity of the graphs. We could then draw a graph which is the mean of all these, and could regard it as expressing the variations of the North Atlantic fluctuation as a whole. (See the lowest graph of Fig 1.) If now we were to plot Labrador temperature below it we should see that its variations were, like those of Iceland pressure, strongly opposed: and on reversing Labrador there would be very strong similarity. So Labrador becomes a good example of the second group. Now we want to know the effect of the North Atlantic oscillation on the pressure temperatures and rainfall of a large number of places; and if in this way we put a hundred graphs under one another, some easy to classify and some doubtful in character, it would be difficult to draw satisfactory conclusions in a manner capable of convenient and accurate expression. So instead of graphs we use numbers. Having found by preliminary investigation the stations which are most representative, we calculate the figures in successive years for the North Atlantic oscillation as a whole, and then work out the correlation coefficients of this with the pressures, temperatures and rainfalls of all the places in which we are interested. These coefficients are plotted

in Fig. 2, and in its top chart we see that the rise of pressure with a positive fluctuation is greater as far east as Vienna and as far west as the Bermudas than it is at the Azores. There is also to be seen in the second chart conspicuous warmth in the east of the United States as well as in north-west Europe, and marked cold to the south-east of the Mediterranean as well as along the north-east of North America. On rainfall, in the lowest chart, the influence is less widespread. The small amount of persistency is shown in Fig. 3. The first of its three graphs shows how

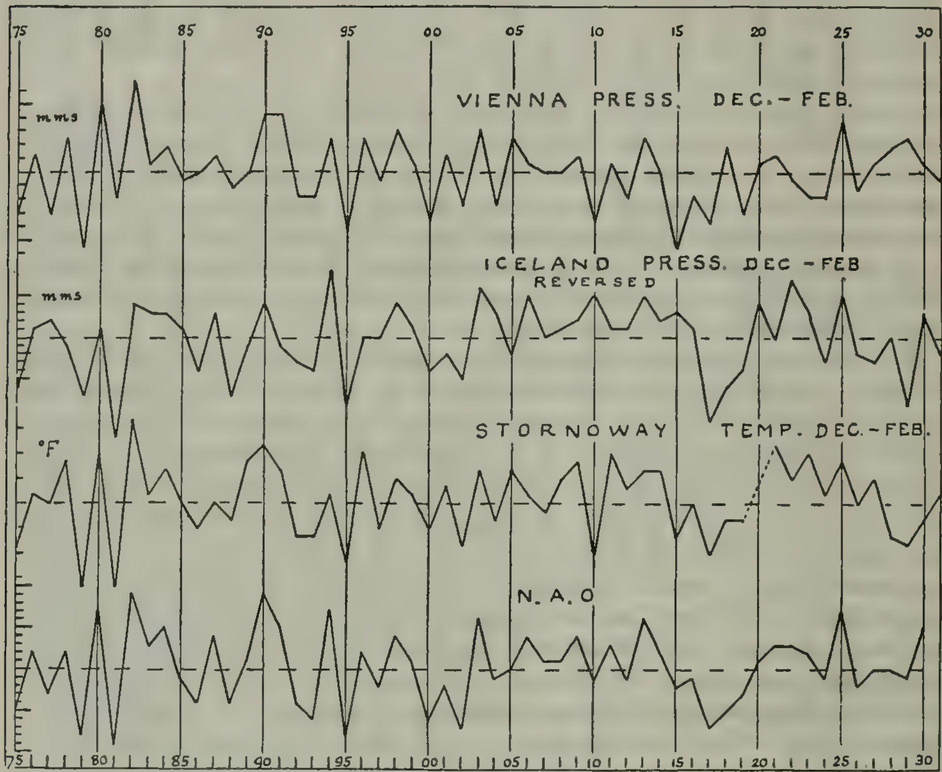


FIG. 1.—N. Atlantic Oscillation.

close are the relationships of pressure in December with the figures expressing the fluctuations of the North Atlantic in that month ; the second and third, which give the relationships of pressure and temperature in January with the fluctuations of the oscillation of the December before, show that little effect of the December conditions survives after a month.

The more critical in my audience may object that if you are sufficiently astute in choosing your successive numbers for the fluctuation you can make a certain amount of agreement with any system of pressures and temperatures ; and to this the reply is that the fit is very much closer than can be explained in this way. Others may urge that all these arguments are merely numerical, and quote the jibe that by statistics you can prove anything. But if you wish to understand phenomena you must collect the facts, and if they are numerical it is only in the

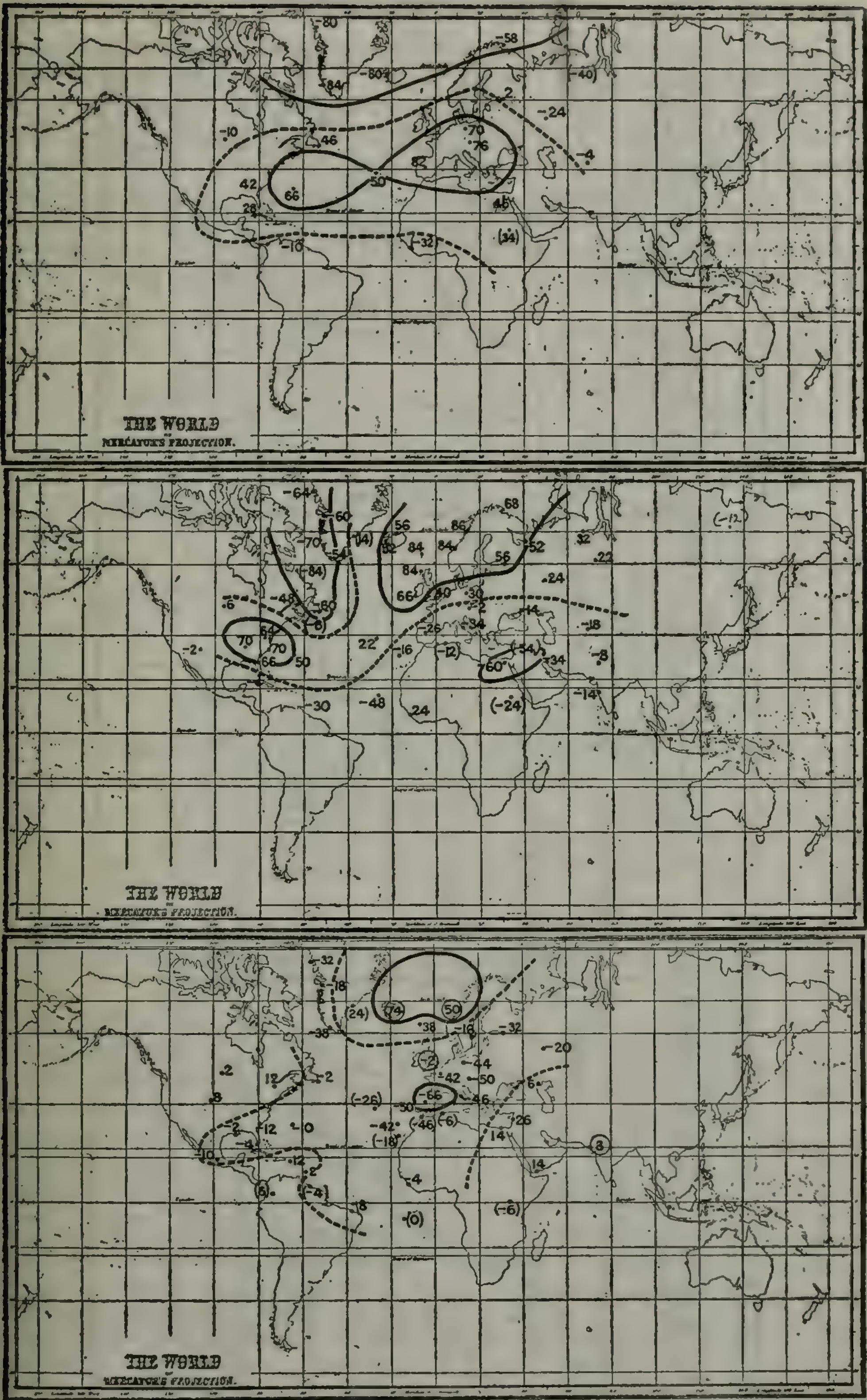


FIG. 2.—Relations of N. Atlantic oscillation with contemporary pressure, temperature and rainfall of December to February. Numbers based on series shorter than 30 years are in brackets; those for areas are in circles.

FIG. 3.—Relations with the N. Atlantic oscillation of December.

very simplest of cases that you can see relationships by merely plotting curves and comparing them. Statistical methods are inevitably forced on us by common sense when we want accurate and reliable inferences from series of data, just as a sextant is forced on a sailor when he wants to determine accurately the altitude of the sun. One who has lost an important lawsuit, owing to the ingenious argument of the opposing counsel, may object that by logic you can prove anything; but that is an inadequate defence for being illogical on all occasions. As a matter of fact, when studying relations of cause and effect statistical methods

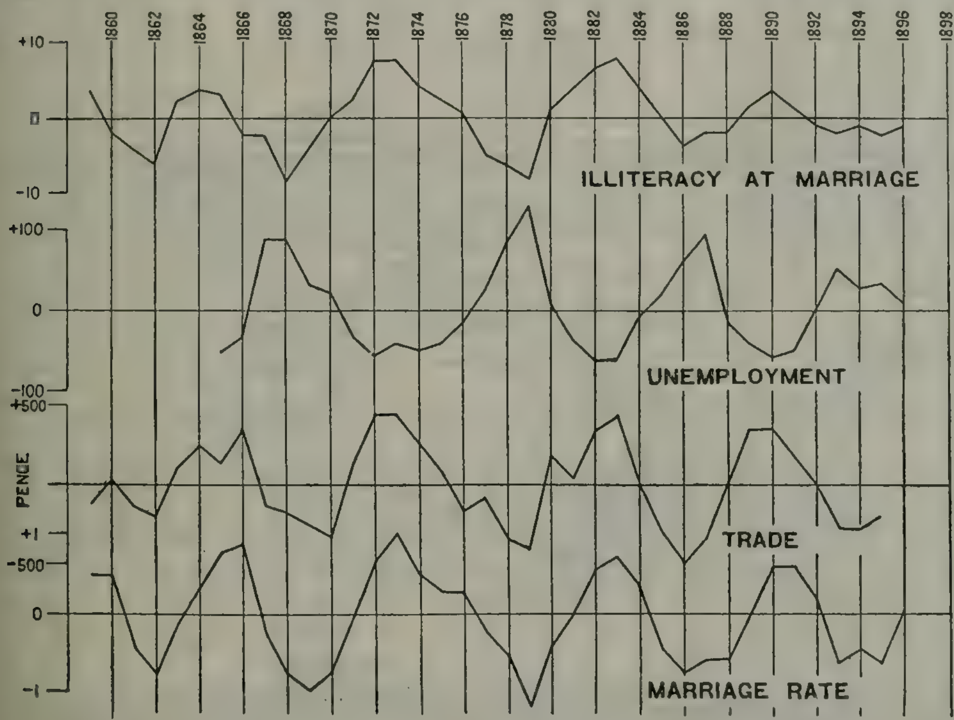


FIG. 4.—Illiteracy and unemployment.

show us what quantities vary together, but strictly by themselves they tell us nothing as to causation. If we compare heights of fathers and sons, we learn that tall sons have tall fathers; but in spite of that fact we are not convinced that the child is literally father to the man.

Let us consider an example from data published in 1906 regarding unemployment and illiteracy as measured by the percentage of persons who could not sign their name in the marriage register (Fig. 4). Clearly the correlation coefficient between these two factors might lead to most undesirable inferences regarding the usefulness of education. But we could not expect to arrive at the truth if we ignored such an important fact as the amount of trade, and on admitting the data of this factor we see at once that faith in the value of our elementary schools need not be uprooted; for the revival of prosperity produced marriage, especially among those in a humble position who could not write, as well as a

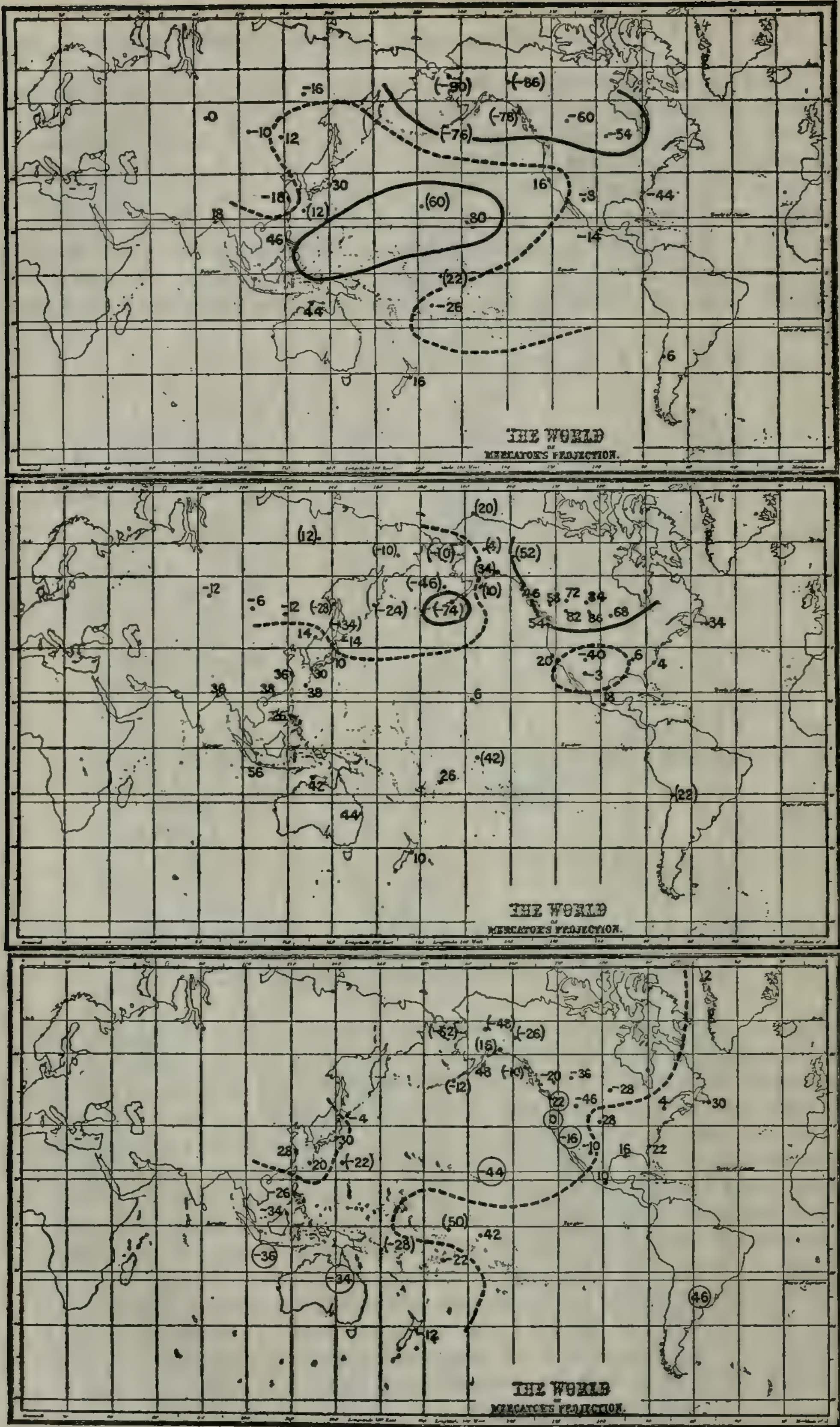


FIG. 5.—Relations of N. Pacific oscillation with contemporary pressure, temperature and rainfall.

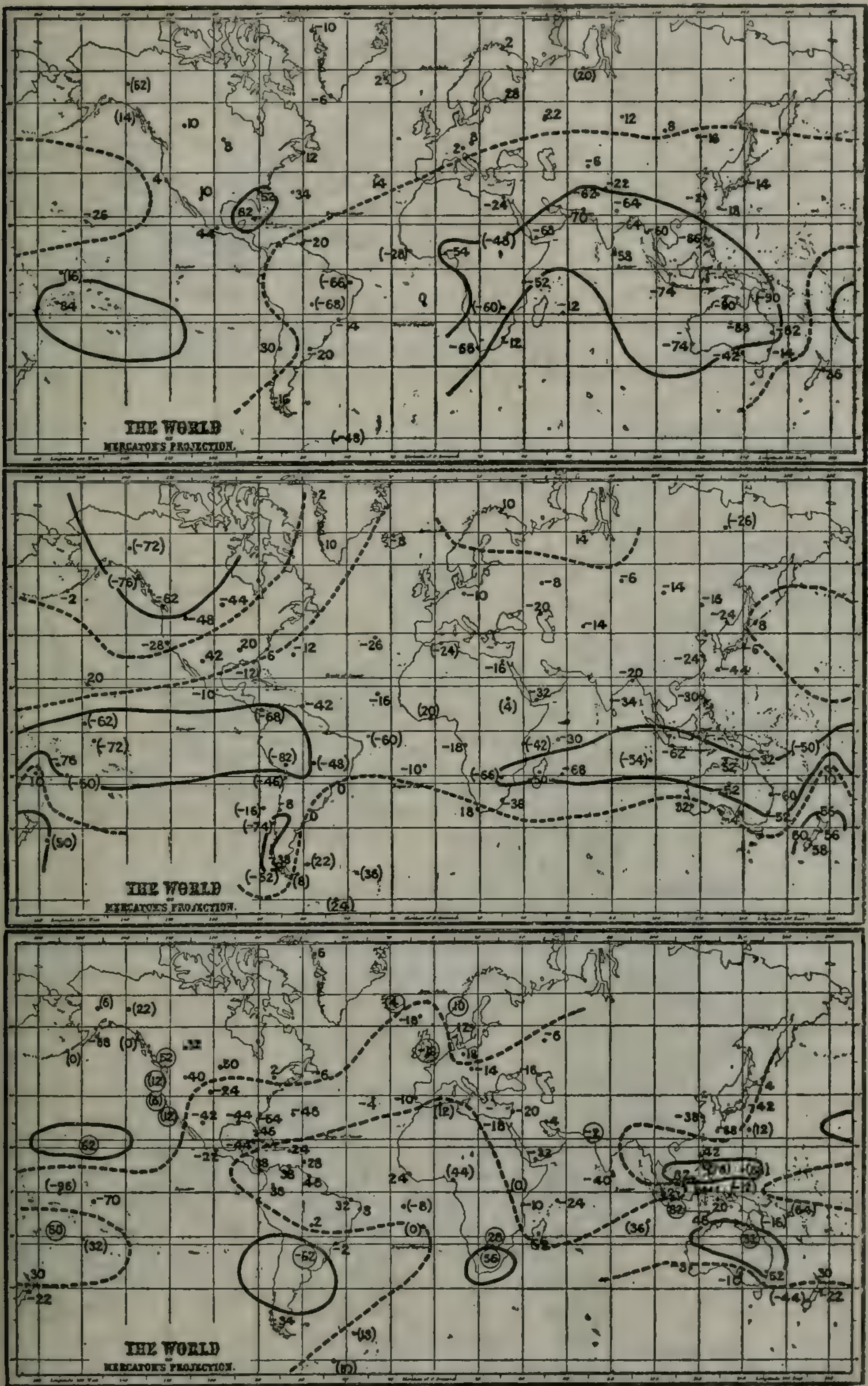


FIG. 6.—Relations of Southern Oscillation of December to February with contemporary pressure, temperature and rainfall.

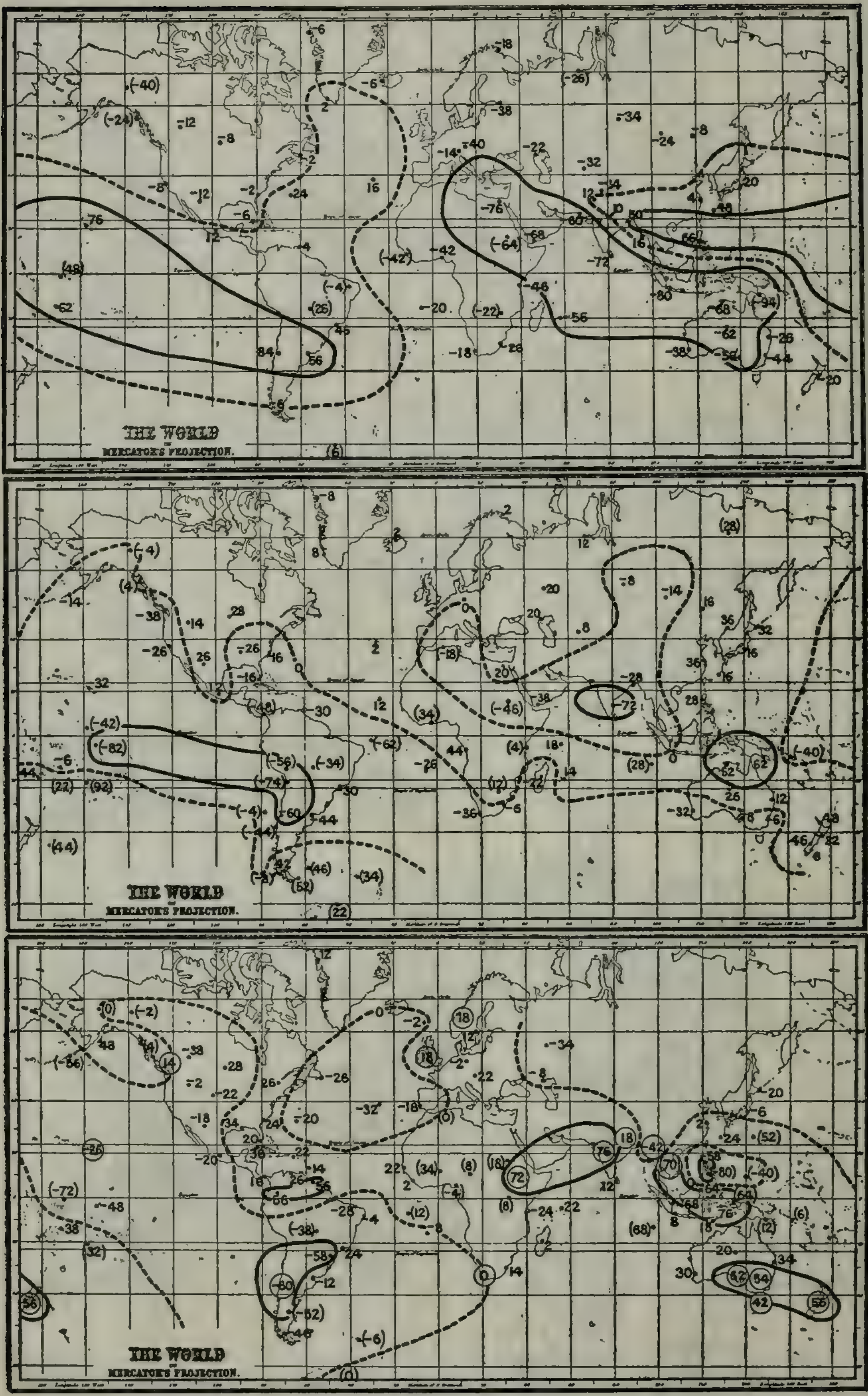


FIG. 7.—Relations of Southern Oscillation of June to August with contemporary pressure, temperature and rainfall.

decrease in unemployment; so that the last two factors varied similarly. We see, then, that we may be misled if we do not take into account all the factors that may be operative. In other words, statistical methods like logarithm tables are invaluable as a tool for giving correct numerical results with the minimum of mental labour; but neither tool possesses imagination or judgment, and neither of them is a substitute for expert knowledge of the subject to which it is applied.

Let us now turn to the North Pacific Ocean which, in spite of its limited access to the Arctic seas, is subject to fluctuations very similar to those of the North Atlantic. A similar treatment yields Fig. 5, in which increased pressure gradients go with high temperature to the north-east and south-west, and low temperature to the north-west and south-east. It will be noted that in both the North Atlantic and Pacific

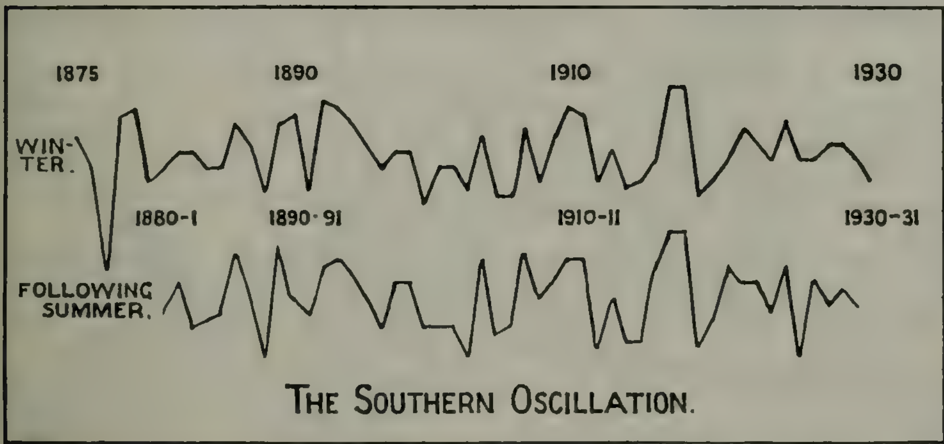


FIG. 8.—Forecast of December to February from previous June to August.

Oceans a fluctuation is classed as positive when the pressure gradient is strong and the wind circulation is active.

The largest known system of related seasonal weather is that called the ‘ southern oscillation ’ (or ‘ southern fluctuation ’), which has features in the southern summer of December to February somewhat different from those of the southern winter of June to August. It will be seen in Figs. 6 and 7 that at both times of the year the fluctuation is called positive when pressure is high in the southern Pacific and low in the Indian Ocean, and temperature is mostly low in the Tropics; but the economic importance is in connection with rainfall, for the fluctuation has a correlation coefficient of over 0·8 with the summer rainfall of north-east Australia, over 0·7 with the monsoon rainfall of India and with the Nile floods, 0·6 with the rainfall of large areas in South America, and over 0·5 with that of a region in South Africa.

A surprising fact comes out on comparing the numerical series giving the characteristics of the summer and winter values of this fluctuation, the control of the southern winter on the succeeding summer being expressed by a coefficient of 0·82, the corresponding data being plotted together in Fig. 8; but the relationship with the previous summer is

FIG. 9.—Indications of D–F pressure, temperature and rainfall from Southern oscillation of previous J–A.

only 0·2. The immediate effect of this is that numerical values of the winter oscillation give us a means of predicting three months in advance, at any rate approximately, the summer values of the oscillation and therefore of the pressure, temperature and rainfall associated with them. In Fig. 9 are the relationships of the values of the pressure, temperature and rainfall of December to February, with the numbers indicating the fluctuation of the previous June to August. These express relationships which have held for about fifty years, and show that we have arrived, not at a mathematical figment, but at a physical reality of commercial value.

These methods of prediction can be improved on by study of the relationships of individual areas. For example, the coefficient of 0·64 of rainfall of north-east Australia with the oscillation of the previous winter becomes 0·79, when we base it on previous pressure at Honolulu,

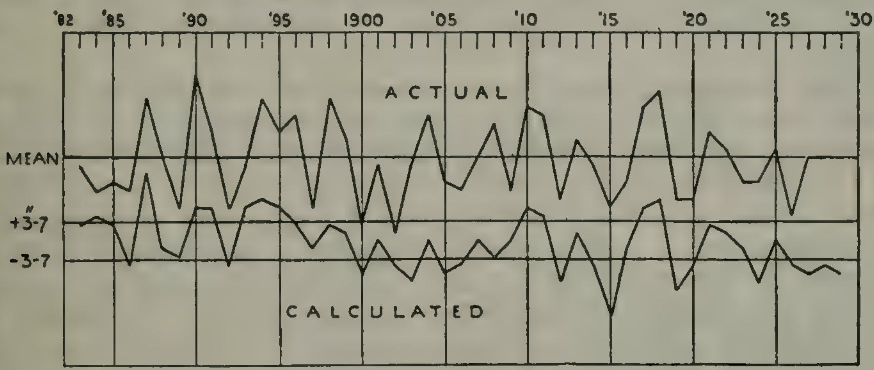


FIG. 10.—N.E. Australian rainfall, October to April.

Port Darwin and South America ; a comparison of the actual rainfall with that given by the formula is shown in Fig. 10. Similarly, the 0·56 of South Africa becomes 0·72. But a certain amount of the improvement effected in this way by selecting the biggest factors is bound to be fictitious, even when there appear to be adequate independent reasons for thinking that the relationships are real ; and, if this precaution is ignored, the more promising the formula, as indicated by the closeness of its apparent relationship, the greater is the likelihood of disappointment.

It must be admitted that a real control of 0·7 by previous conditions is about as good as is now available for forecasting, and the difference between the actual and the forecasted amounts will still be considerable ; so predictions can only be issued with restraint if public confidence is to be won. The natural consequence is silence, except when the indications are markedly favourable or unfavourable : in a race with thirty starters a conspicuously good horse may, without undue risk, be backed to come in within the foremost six, and we may feel confident that a thoroughly bad animal will be in the last six ; but it would be unwise to hazard much on the likelihood that a commonplace individual will finish among the central six. It may at first sight seem a confession

of weakness to issue no forecast when conditions appear roughly normal; but it is better to admit your limitations, and only speak when you can do so with some safety, than to issue predictions when they are little more than guesses.

The objection is sometimes raised that though a foreshadowing of abundant or scanty rain over a region may be right four times out of five, owing to local variations the predictions will not be so successful when applied to a particular farm; and it must be admitted that this criticism is valid. But in England, as I learn from Sir John Russell, there are modifications of treatment and manuring that are appropriate before wet seasons and others before dry; in South Africa, in hilly country, the upper levels are better for cultivation in wet years and the lower ones in dry years; in India, if the rains fail, cotton and millets will grow though the ordinary crops may perish. We may hope that, when our methods have improved, the prediction when applied to a particular farm will be right at least three times in five years; and if this is consistently acted upon, it will prove of material value in the long run.

Of further applications of these methods some are worthy of a passing notice. For Siam, whose summer rain has a coefficient of 0·7 with the contemporary southern oscillation, a former Indian colleague has worked out a foreshadowing formula with a relationship of 0·8. And at length China, which has suffered terribly from floods as well as droughts, is receiving attention. A graduate from Shanghai, now working in London, finds that the Yangtse valley and three areas along the coast have enough data for a preliminary investigation, and has worked out formulæ for prediction with coefficients between 0·6 and 0·7. Mention should also be made of the researches of Okada in connection with the rice crop of Japan.

Let us now turn from the academic to the practical, and see how far these theoretical methods justify themselves in actual experience. I believe that the earliest regular seasonal forecasts based on meteorological instead of astrological data were those of the Indian monsoon of June to September, started half a century ago in India by H. F. Blanford, and depending mainly for their success on the ill-effect upon the monsoon of excessive winter or spring snowfall in the Himalayas; finally, however, he made the big generalisation that droughts might be associated with unusually high pressure over a great part of Asia, at Mauritius and in Australia. Eliot continued the monsoon forecasts from 1887 to 1903, but data in those days were scanty; he attempted far too much detail, his mode of expression was somewhat pontifical, and the newspapers became sarcastic; so latterly he obtained immunity from criticism by printing the forecasts as confidential documents. The gradual introduction of statistical methods in India has undoubtedly led to improvement; but as we have seen it is much easier to predict the rainfall of December to February than that of June to September, and the length of the series of Indian data is not yet great enough to give complete reliability. After careful scrutiny I estimate that of the forecasts issued before the monsoon periods from 1905 to 1932 two-thirds were correct;

but I consider that this is not good enough and that we have been too ambitious. Also while the approximate prediction formula of 1908 has stood the test of time with credit, the later ones of 1924 for north-west India and the Peninsula separately, although certainly better in theory, have not, in the short period of trial, proved so successful. The contrast between the working of the formulæ before and after their date of preparation will be seen in Fig. 11.

Happily in Southern Rhodesia, which in 1922 adopted statistical methods similar to those of India with only twenty-four years of data to work upon, the results have been eminently satisfactory. Out of eleven

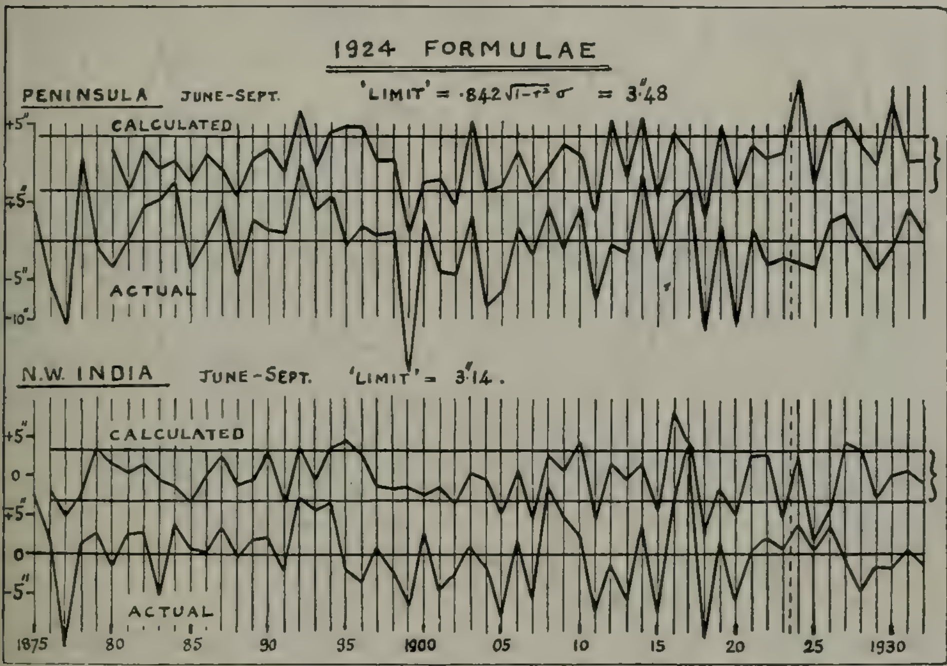


FIG. 11.—Calculated and actual Indian rainfall.

years since publication was begun, there have been eight in which a departure of over 3 in. was given by the formula, and in seven of these the character was correctly indicated (Fig. 12).

At Batavia the efficient Dutch observatory under Braak started in 1909 to issue forecasts founded on the simple rule that low pressure from January to June was followed by abundance of rain from July to December. The rule demanded a more complete presistence of pressure than actually prevails, and in 1927 Berlage adopted a formula based on three local conditions, together with data of the rare rains of northern Peru : this gives, on paper, a relationship of over 0·8.

In Australia calamitous failures in the rains have long demanded forecasts, and these led to the production of weather cycles, which broke down so frequently that their use was discarded. In spite of this experience, however, Hunt, the Commonwealth Meteorologist, put

forward in 1929 a theory of a four-year period, based on the cooling effect of the widespread growth of luxuriant vegetation produced by the rainfall in areas that were parched. I believe that the theory has not been adopted officially.

When we turn from the tropical and subtropical to the temperate regions, where the persistence of conditions is in general conspicuously

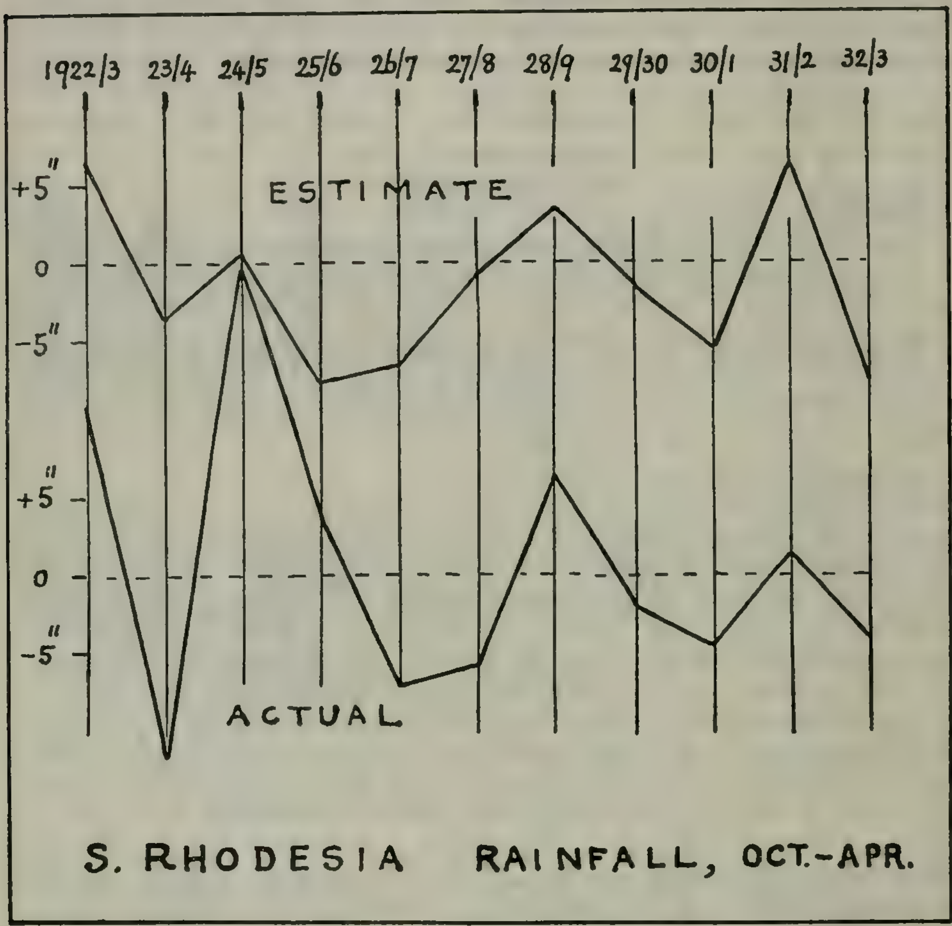


Fig. 12.

smaller, we must expect greater difficulties in making long-range forecasts. In America the relations of weather and crops have probably been worked out more scientifically than in any other country, so that the commercial value of reliable predicting has long been recognised; and not only by farmers, but by those interested in water supply, in power schemes, in transport and in commerce generally. Thus one of the Californian hydro-electric companies makes its own forecasts, because it may spend four million dollars more for crude oil in a dry than in a wet year. In a country of exuberant vitality it is not surprising that many efforts should

have been made to provide for the general demand. In an article in 1927, by C. F. Brooks, we read that in the absence of forecasts 'western farmers have paid a "rainmaker" thousands of dollars at a time' actually to produce rain; that during the previous ten years 'well over fifty long-rangers of greater or lesser repute have been publishing and, in a great many cases, accepting money for worthless or damaging forecasts.' As in Europe, they have predictions based on occurrences on critical days, such as Candlemas or St. Swithin's, as well as on the doings of animals and birds. Thus Brooks quotes from an almanac of 1870: 'When you see 13 geese walking injun file and toeing in you can deliberately bet yure last surviving dollar on a hard winter, and grate fluktuousness during the next seazon in the price of cowhide boots.'

Undeterred by the difficulties, G. F. McEwen, of the Scripps Institution

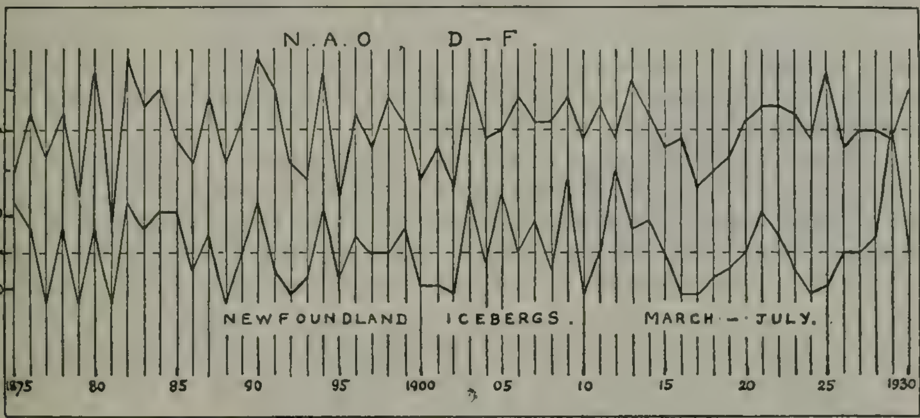


FIG. 13.—Atlantic Icebergs and the previous oscillation.

of Oceanography in California, has for some time been forecasting rainfall by empirical methods, and at first attained considerable success, largely on the basis of a short series of ocean temperatures. These, however, as he has recognised, have not of late made good their early promise; and he is driven to using sunspot numbers, a cycle of five or six years, and a complex method of smoothing in the hope of attaining reliability.

A less difficult task confronts the International Ice Patrol Service of the United States in their desire to obtain advance information of the amount of Arctic ice drifting into the western North Atlantic. I do not know what progress has been made, but the dependence on the previous North Atlantic oscillation, with which there is a coefficient of 0·60, would appear to suggest a useful starting-point (Fig. 13).

In Europe the only seasonal forecasts known to me that have a scientific foundation, and have been made for a number of years, are those of Sweden and Russia. In Sweden Wallén has for eighteen years made predictions for rainfall and for the height of water. Regarding rainfall, he smoothes by taking the sums of consecutive twelve months; and then, assuming

that the nature of the fluctuation so disclosed will not change suddenly, he forecasts that the total rainfall of some definite period, usually six months or a year, will be greater, or less, than it was in the previous year. Now a moment's thought will make it clear that a man will in the long run be right three times out of four if, when last year's rain was in defect, he predicts an increase, or if it was in excess he forecasts a diminution. So I think it is not unfair to say that success under the Swedish conditions begins at 75 per cent. The success actually attained is 82 per cent., which is encouraging; and the success in dealing with water levels is phenomenally great, being slightly over 90 per cent.

The seasonal conditions of Russia, which are not very closely related with those of the North Atlantic, have been carefully examined by W. Wiese. In 1923 the Hydrometeorological Office of Leningrad started publishing forecasts of ice in the Barents Sea, and out of seventeen monthly forecasts of which I have information fifteen were approximately correct. Predictions of the rainfall of April and May in central and east Russia were initiated at the same time, and all the first four years they were approximately correct: the biggest difference between the actual and forecasted amounts was only 20 per cent.

No account of European activity in this department could ignore the enterprise of Prussia four years ago in creating at Frankfurt a.M. a post for research into long-period forecasting. Dr. Franz Baur has for the present wisely limited his activity to the issue of a forecast of ten days; it would be impossible to expect results under these conditions which are as accurate as those of daily weather work, but I am informed that their standard fully demonstrates the trustworthiness of the principles employed. It is only by experiments of this kind that satisfactory methods of prediction can be developed.

We may now pass to the consideration of improvements in our methods, and the fundamental question at once arises—what is the physical cause of seasonal fluctuations? We should naturally look for it in variations in the energy received from the sun, and it is surprising that an increase in solar activity as measured by sunspots produces a slight decrease in the circulations in the North Atlantic and the North Pacific. In the southern fluctuation the tendency of numerous spots is to produce positive values, but even there the biggest seasonal correlation coefficient is only 0·26, which is much too small to provide the explanation that we seek. Moreover, it probably arises because a positive fluctuation is associated with low temperatures between latitudes 40° N. and 40° S.; and these are linked with an increase in sunspots.

In order to verify that the daily pressures are not produced by short-lived emanations from the sun tabulations of the relationships between daily and weekly, as well as the monthly and seasonal, values at distant places have been made; for if the daily values over the earth are controlled from outside there will be close parallelism between these daily and weekly pressures. It was found that between 31 daily contemporary pressures at Honolulu and Batavia the coefficient was $-0·12$, which is negligible; between 39 weekly ones it was $+0·10$, between 47 monthly June pressures it was $-0·12$, and between the pressures of 47 three-

monthly seasons of June to August it was $-0\cdot46$. Between Samoa and Batavia December pressures the coefficient was $-0\cdot38$, and for the season December to February it was $-0\cdot60$. Thus it is between the characteristics that persist over months, not over days or weeks, that relationships exist.

Being forced off short-lived phenomena we search for an explanation in terms of slowly changing features, such as ocean temperatures; and the big variations from year to year in the amount of pack ice in the antarctic seas forces itself on our attention. But here the reports of twelve years from the South Orkneys yield a relationship of only $0\cdot32$ with the southern fluctuation, instead of about $0\cdot9$, as we should want in a prime cause; and the variations at the South Orkneys come after rather than before those of the southern oscillation. The biggest ocean region is the Pacific, and as an index of its seasonal water temperature we may use the corresponding air temperature of Samoa, which shows a greater persistence than any factor in the world as yet examined; the relationship between its summer and autumn values is as large as $0\cdot94$. But unluckily the correlation coefficients show clearly that it is mainly the southern fluctuation in winter that controls the Samoa temperature. Thus a short-cut to the explanation of our fundamental problems seems as far away as ever. Our three big fluctuations each form a system of changes which are apparently held together by meteorological links: and there is, in my opinion, as yet no satisfactory proof of any free periods associated with them.

Let us now consider in what direction new developments seem likely. A moment's reflection will convince us that in view of the variations of rainfall over large areas, such as Brazil and Central Africa, which are scarcely affected by the three big fluctuations, there must be others, some of which are probably on a big scale. For example we should, on the analogy of the northern oceans, expect a fluctuation of pressure between the antarctic low pressure belt and the high pressure belt of 30° S. We are at once reminded of the marked opposition which Simpson found during the short period of four years for which data were available between pressure at McMurdo Sound and that in a belt round the earth extending from about 25° S. to about 50° S. All students of this subject have found it natural to regard the fluctuations in the amount of pack ice in the antarctic seas as likely to control sea and therefore air temperatures over large regions, and the most southern station from which as many as twenty-five years of data are forthcoming is the South Orkneys. Its winter pressure does show the opposition that we should expect with that of Australia, but not with the high-pressure region of South America or Mauritius; so that it gives little support to the view that there is a general pressure oscillation between the low and the high pressure belts of the southern hemisphere. On the other hand, the air temperature at the South Orkneys may be regarded as an index of the sea temperature: and as the ocean current through the Drake Passage would take about a year to reach South Africa, we are not astonished at the relationship of $0\cdot56$ between the South Orkneys air temperature in winter and that of the next winter at Cape Town. This is not, however, as close as the corre-

sponding relationship of 0·84 shown in Fig. 14 between the winter temperature at New Year Island at the extreme south-east of South America, and that at Cape Town a year later. The far greater influence of New Year Island is interesting, since between Cape Horn and the South Orkneys there runs E.N.E. a line which the recent *Discovery* expedition calls the Antarctic Convergence ; here the cold antarctic water meets the northern warmer water and dives under it. So while the current flowing past New Year Island can after a year approach South Africa that from the South Orkneys is cut off by a barrier.

If I may summarise these remarks, I would say that although seasonal foreshadowing is still very imperfect it has come to stay ; for situations will arise from time to time, as they did in India in 1905, in which it

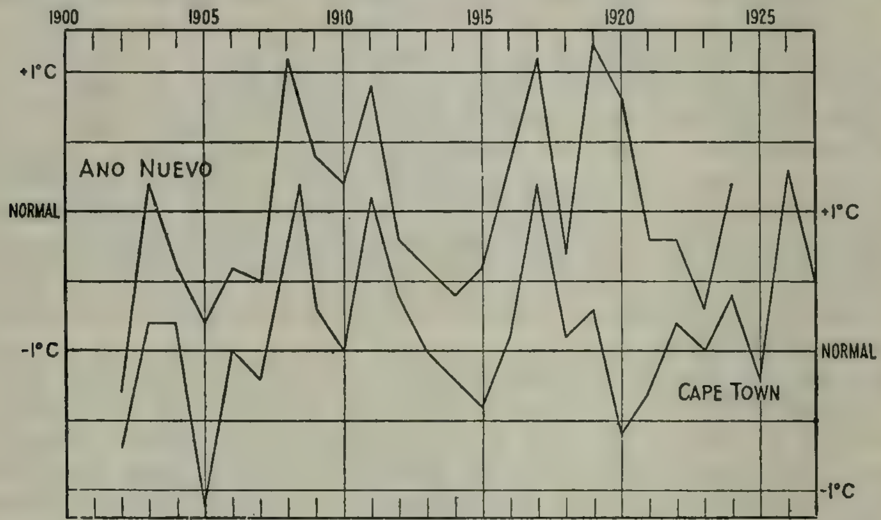


FIG. 14.—Departures from normal of Ano Nuevo temperature, June to August, and of Cape Town temperature, June to August, of following year.

can be foreseen with practical certainty that rains will fail and a warning will then be of great value. But those who prepare formulæ by the selection, based merely on the closeness of their apparent relationship, of a few out of many factors must remember that they cannot expect the value of all these factors to be maintained ; and if they have a forecasting formula which on paper works out with a coefficient of, say, 0·75, they must realise that this is in reality probably not more than 0·6, or in some cases even 0·4. And I would plead for a much severer standard in handling questions of periodicity. If these views are right, no anticipations should be published except on the strongest evidence of excess or defect until the experience of fifteen or twenty years has justified a less cautious policy.

Finally I would express the hope that the subject may, by its potential value to the race, and by the many-sided nature of its interests, enlist the services of some of my hearers who are qualified to unravel some of its intricacies.

SECTION B.—CHEMISTRY.

NATURAL COLOURING MATTERS AND THEIR ANALOGUES

ADDRESS BY

PROF. ROBERT ROBINSON, F.R.S.

PRESIDENT OF THE SECTION.

On taking the Chair of this Section I should like to express my thanks for the great honour which you and the Council of the British Association have conferred on me.

Although the subject which I have selected for my address is necessarily somewhat technical, it occurred to me that the problem of flower colour is of general interest, and the gist of what I have to say is a contribution to the answer to the question: why are some flowers *blue* and others, containing the same pigment, *red*? In the interests, too, of members of this audience who are not organic chemists I propose to allow the spoken to diverge from the written word, and I shall venture also to attempt the performance of a few simple experiments.

In every country and throughout the ages emotions have been stirred and curiosity aroused by the display of colour in Nature, but it is perhaps not generally realised that the ready availability of artificial colouring matters suitable for every kind of tinctorial purpose, from boot polish to finger nails, is a comparatively recent development. We read of the ancient Tyrian purple, the purple of kings, and of the red cosmetic pigments of natives of the Orinoco, so rare that they were used as the basis of exchange; in contrast, at the present time dyes of all shades may be indulged in to an extent controlled certainly by individual courage, taste and discretion, but hardly at all by limitations of purse or social status. It may be that this ' freedom of the hues ' has been enjoyed for so brief a period that a state of equilibrium has not yet been reached and we are not using our privileges in this matter either as fully as possible or as wisely as possible.

It is not, however, for an organic chemist to discuss such problems as that of masculine sartorial conservatism on the one hand, or to attempt an estimate of the æsthetic value of the film-fan magazine cover on the other.

The chemist has been attracted to the investigation of natural and artificial colouring matters for a variety of reasons, including not only colour-pleasure, the incentive of the knowledge that chlorophyll and hæmoglobin perform some of the most important functions in vital processes, and the industrial importance of dyestuffs and pigments, but also on account of the fact that visible colour more than any other property facilitates the experimental study of organic substances whether by analysis or synthesis. It furnishes a standard of homogeneity or a measure of concentration, it is an invaluable guide in the search for methods of

separation and purification, and it at once indicates, by its appearance or disappearance, the occurrence of a chemical reaction. Small wonder that the successful outcome of the investigation of many colourless substances has awaited the discovery of some characteristic colour-reaction ; a noteworthy example being Vitamin A. Odour is a more specific property than colour as judged by the eye, and in a more limited field it has proved equally useful to chemists who prefer to follow their noses. However, we cannot yet resolve odours in a spectrum.

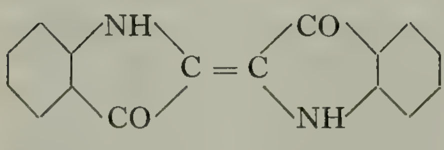
Thus the pursuit of a fascinating object has been along a path of relatively low resistance and the pioneers have been richly rewarded.

Like a list of best books, a catalogue of outstanding achievements invites destructive criticism. I do not fear this, however, in recalling the researches of Laurent, Kekulé, Baeyer and Heumann on indigo ; of Sir William Perkin, Hofmann, Otto and Emil Fischer, Meldola and many others on the basic dyes ; of Griess and his host of followers on the azo-compounds ; of Arthur Perkin and of Kostanecki on the flavones and flavonols ; of Willstätter on the respiratory pigments and the anthocyanins ; and, not least, of Hans Fischer on the synthesis of the prosthetic group of the blood pigment.

No attempt can be made to cover this vast field, but the mere mention of these topics serves to prove the immense theoretical and practical value of a study of organic colouring matters. The work proceeds and a long chapter on the natural carotinoid pigments is even now being written by Karrer, Kuhn and others ; it is of great chemical and biological interest.

Before dealing with the special group of the anthocyanins, some aspects of which have recently been studied at Oxford, attention may be directed to the analogies in constitution existing between natural colouring matters and artificial dyestuffs.

As the result of the researches of Baeyer, indigotin is generally regarded as having the formula I, but a technical digression may be made to the effect that the formula II has not yet been completely disproved.



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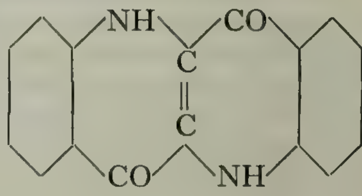

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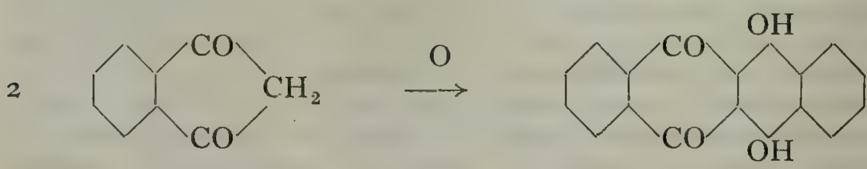
The oxidation of indoxyl to indigotin appears to favour I, but then Gabriel has shown that the oxidation of diketohydrindene (III) by means of alkaline persulphate furnishes dihydroxynaphthacenequinone (IV).



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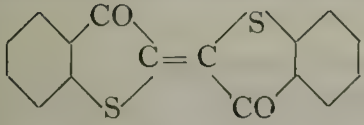
All the indigotin syntheses can give II just as well as I, and II can yield isatin on oxidation. The recent researches of E. Hope prove that some of the products of the action of benzoyl chloride on indigotin possess the skeleton of II, but of course this may arise from an intramolecular rearrangement. The chief argument against II is derived from a consideration of the numerous classes of indigoid dyestuffs which are easily formulated on the model of I.

The industrial analogues of indigo are its substituted derivatives, the thioindigos (*e.g.* V) and similar indigoid dyes, and indanthrone (VI). The first-mentioned classes were made in imitation of the indigotin



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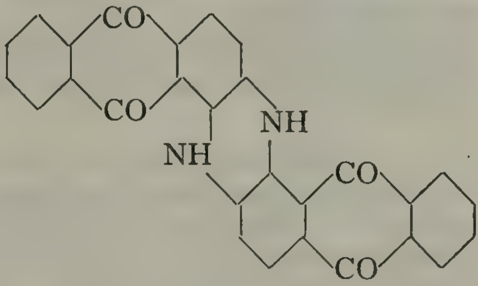
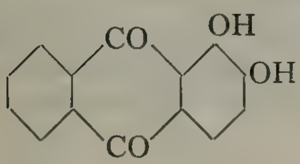


(VI)

structure, but in the case of indanthrone flattery was unconscious. Both indigotin and indanthrone contain the chromophoric quinone group —CO—Ċ = Ċ—CO— and closely situated auxochromic —NH— groups.

Graebe and Liebermann's recognition of the constitution of alizarin (madder) (VII) led, as in the case of indigo, to the industrial synthesis of the colouring matter itself and of numerous derivatives and analogues.



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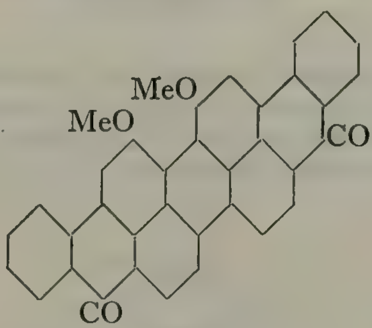

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At the present time we recognise in retrospect that the most important outcome of the work on madder was the attention focussed on the study of anthraquinone and its derivatives. It may seem a far cry from the adjective natural dyestuff to the modern vat dyestuff Caledon Jade Green (VIII), but the descent is in the direct line—alizarin, Alizarin Blue, benzanthrone, dibenzanthrone, Jade Green. Technical analogues of the anthocyanidins are to be found in the phthaleins, pyronines and rhodamines, and some more or less close dyestuff analogy can be found to correspond with most of the series of natural colouring matters.

The most recent, and certainly one of the most interesting, examples of this kind is found in the phthalocyanines which contain a porphyrazine structure, that is the porphin skeleton of the natural porphyrins in which some —CH= groups are replaced by —N=. Dr. Linstead will shortly give an account of his investigations of these substances and of their remarkable properties.

It was primarily with cognisance of Dr. Linstead's work that I ventured to direct your attention to *analogues* of natural colouring matters; this is at the technical end of the scale, and in contrast Professor Kuhn has kindly consented to describe some novel natural colouring matters of high biochemical interest.

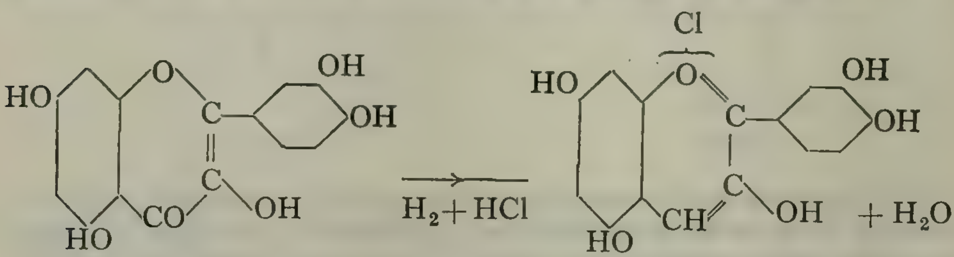
The following sections of this address deal with developments of the chemistry of the red, blue and violet colouring matters of flowers and blossoms.

Structure and Synthesis of the Anthocyanins.

A brief description of the chemistry of the anthocyanins is necessary at this stage. The brilliant and pioneering researches of Richard Willstätter and his co-workers (1914–) established the main features of the chemistry of the anthocyanins which were recognised as saccharides, occasionally acylated, of the anthocyanidins. They exhibit amphoteric character, forming salts with both acids and bases. Thus the violet pigment *cyanin*, which can be isolated from blue cornflowers, red roses, deep red dahlias and other flowers, forms a blue sodium salt and a red hydrochloride. The hydrolysis of the latter by means of hot aqueous hydrochloric acid into cyanidin chloride and glucose is represented by the equation:

$$\underset{\text{cyanin chloride}}{C_{27}H_{31}O_{16}Cl} + 2H_2O = \underset{\substack{\text{cyanidin}\\ \text{chloride}}}{C_{15}H_{11}O_6Cl} + \underset{\text{glucose}}{2C_6H_{12}O_6}$$

The constitution of cyanidin chloride (X) has been established by analysis and numerous syntheses; the first of these (Willstätter and Mallison) utilised the reduction of quercetin (IX) by means of magnesium in aqueous methyl alcoholic hydrochloric acid solution (demonstration).

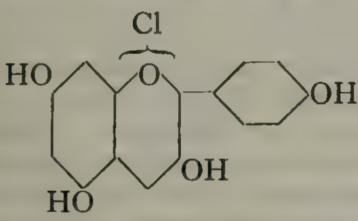


(IX) (X)

In this process a widely distributed anthoxanthin yields a widely distributed anthocyanidin, and the temptation to assume that similar reactions occur in the plant laboratory is very great. There is, however, very little justification for this view and the experimental support brought forward in its favour will not survive careful scrutiny. The alleged

crystalline anthocyans prepared by the reduction of natural flavones or plant extracts containing them are nothing but the said flavones with a small proportion of adsorbed colouring matter of anthocyanidin type. It seems much more probable that the flavones and anthocyanins are independently synthesised, although perhaps from a common starting point. The existence of genetic factors which control the occurrence of anthoxanthins independent of that of anthocyanins is strong evidence in favour of this view.

The anthocyanidins which have been isolated are the following: pelargonidin (XI), cyanidin (XII), peonidin (XIII), delphinidin (XIV), petunidin (XV), malvidin (XVI) and hirsutidin (XVII), represented as chlorides. All have been synthesised by unambiguous methods and the synthetic specimens have been carefully compared and identified with the



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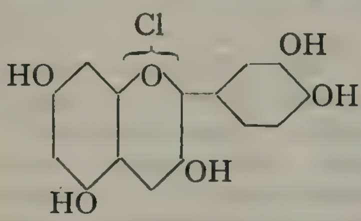

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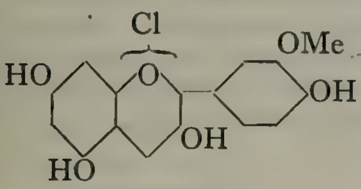

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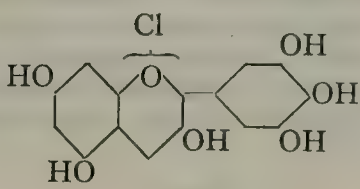

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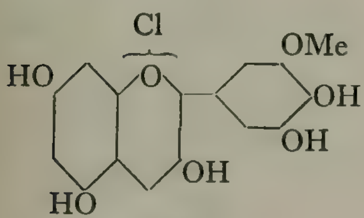

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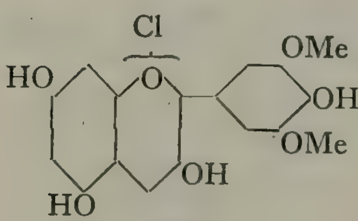
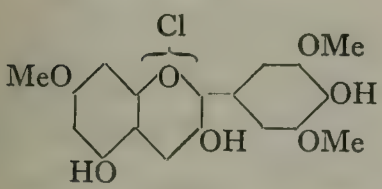
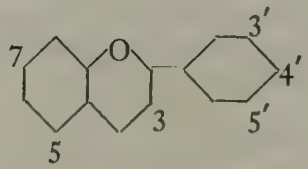


(XVI)



(XVII)



Numbering Scheme.

natural products. It will be observed that pelargonidin, cyanidin and delphinidin are the fundamental types, peonidin being a methyl ether of cyanidin and petunidin, malvidin and hirsutidin being, respectively, the mono-, di-, and trimethyl ethers of delphinidin.

The greater number of the anthocyanins fall into a comparatively restricted number of categories, including :

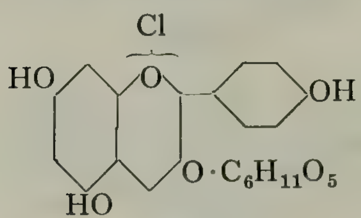
(*a*) the 3-monoglucosides and 3-monogalactosides,
(*b*) the 3-rhamnoglucosides and other 3-pentoseglycosides,
(*c*) the 3-biosides,
(*d*) the 3 : 5-diglucosides, and
(*e*) the acylated anthocyanins.

It is unnecessary to recount the steps taken in reaching these conclusions, but they have been finally justified by synthesis in many instances.

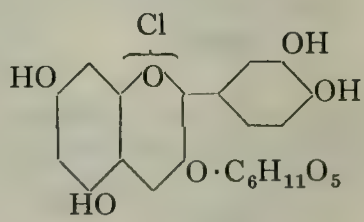
In group (*a*) we find callistephin (XVIII), the monoglucoside of pelargonidin occurring as one of the pigments of the aster and as the main pigment of scarlet carnations and many other flowers ; the related galactoside, fragarin, is the colouring matter of the strawberry.

In the cyanidin series the corresponding pair is chrysanthemin and idæin (XIX), the former of wide distribution and the latter occurring in the skins of cranberries and in the leaves of the copper beech.

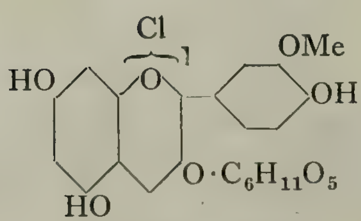
Peonidin 3-monoglucoside (XX), termed oxycoccicyanin, is found in the skins of the larger American cranberries and œnin or malvidin 3-monoglucoside (XXI) is the colouring matter of the skins of purple-black grapes, as well as of certain cyclamen and primulæ. The delphinidin representative undoubtedly occurs in bilberries in admixture with other pigments, and it has not yet been fully examined ; the petunidin and hirsutidin representatives have not been isolated from natural sources, although there is reason to believe that the former occurs in the berries of the Darwin barberry and the latter has been synthesised.



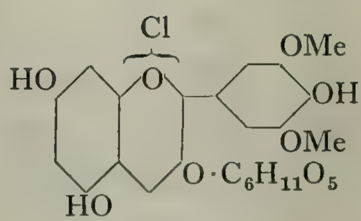
(XVIII)



(XIX)



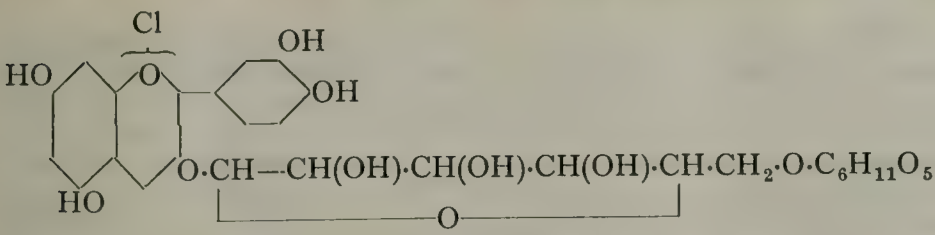
(XX)



(XXI)

In groups (*b*) and (*c*) we find large classes of anthocyanins of which only a few representatives have been closely studied. These include keracyanin (cyanidin 3-rhamnoglucoside), probably identical with antirrhinin (isolated by Miss R. Scott-Moncrieff), and mecocyanin (XXII),

a pigment of red poppies which is now recognised by synthesis as cyanidin 3-gentiobioside. There is very little doubt that pelargonidin

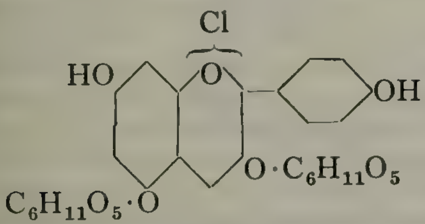


(XXII)

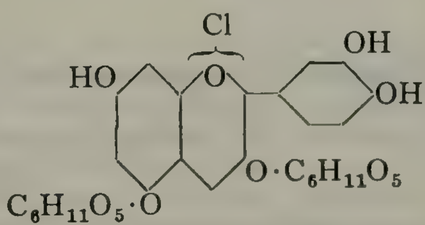
3-rhamnoglucoside colours the scarlet gloxinia and that pelargonidin 3-biosides are of widespread occurrence, for example, in the ordinary orange-red nasturtium and in the flowers of the scarlet runner bean.

The anthocyanins of groups (*a*), (*b*) and (*c*), when derived from the same anthocyanidin, exhibit similar behaviour as indicators. Thus chrysanthemin, keracyanin and mecocyanin all give a violet solution in aqueous soda and this becomes blue on the addition of caustic alkali. On partial hydrolysis mecocyanin and antirrhinin actually yield chrysanthemin.

The anthocyanins of class (*d*) are the most widely distributed and best-known members of this series of natural pigments ; they include pelargonin (XXIII), the colouring matter of the scarlet pelargonium and possibly the first anthocyanin to be obtained in a crystalline condition (Molisch's experiment), also cyanin (XXIV), the isolation of which from the blue cornflower by Willstätter and Everest in 1914 was the first of an impressive series of investigations.



(XXIII)



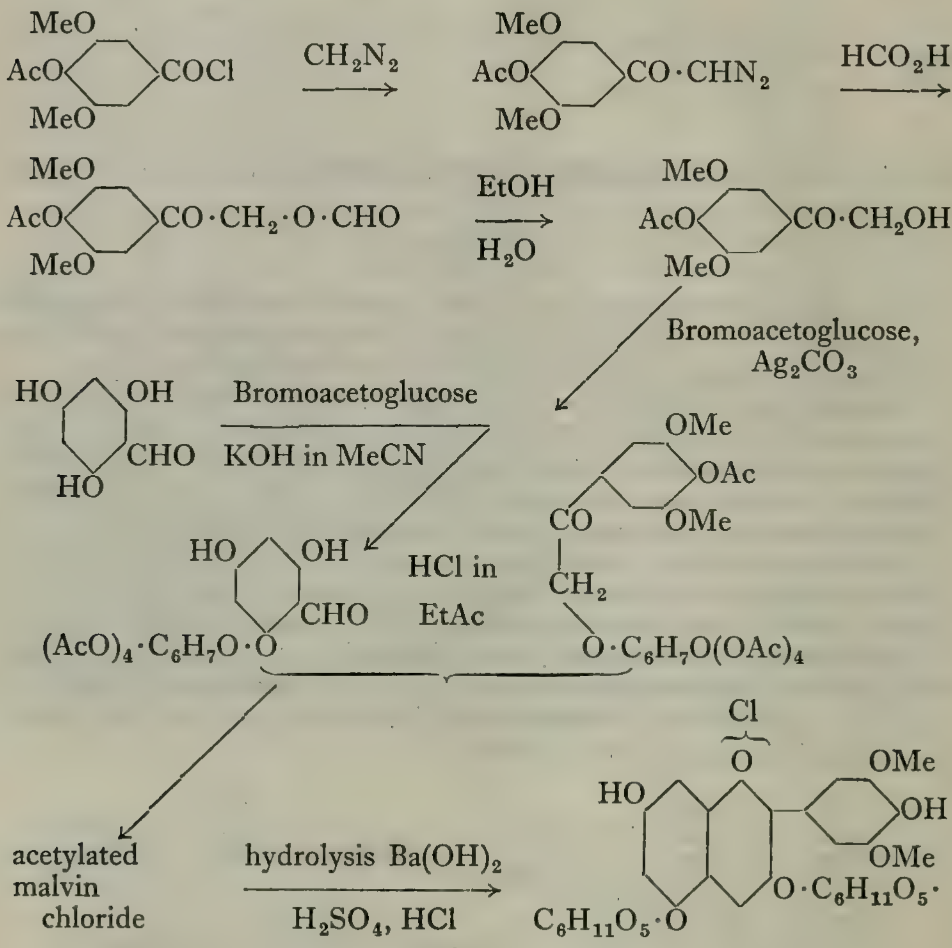
(XXIV)

Peonin from the deep red peony and malvin (XXV) from the wild mallow or from certain primulæ, are the peonidin and malvidin representatives in this group, which is completed by petunin and hirsutin. Quite recently the delphinidin member has been isolated from *Salvia patens*.

The anthocyanins of group (*d*) differ from those of groups (*a*), (*b*) and (*c*) in their alkali-colour-reactions and in their marked instability to aqueous sodium hydroxide. Thus cyanin, which compares with mecocyanin in group (*c*), gives a pure blue solution in aqueous soda and the dilute solution becomes very quickly yellow on the addition of sodium hydroxide (demonstration).

Pelargonin, cyanin, peonin, malvin and hirsutin have been synthesised

and an example of the methods adopted may be schematically indicated in the case of malvin.



(XXV)

The anthocyanins can be characterised and qualitatively distinguished by their distribution between immiscible solvents, and in the case of disaccharides the use of *n*-butyl alcohol is convenient (demonstration).

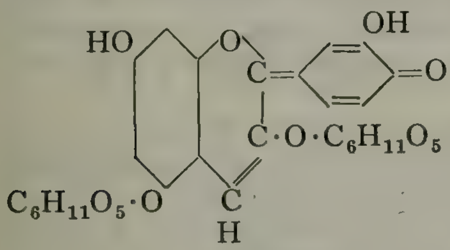
Acylated anthocyanins occur in all the anthocyanidin series ; thus, on hydrolysis, delphinin, the pigment of species of delphinium, furnishes *p*-hydroxybenzoic acid as well as glucose and delphinidin.

Many other delphinidin derivatives are acylated by means of *p*-hydroxycinnamic acid, probably attached to the sugar hydroxyls, and pelargonin and cyanin also occur in acylated forms. These so-called *complex* anthocyanins are characterised by high distribution numbers ; they are usually acylated 3 : 5-dimonosides, but in the delphinidin series, gentianin and violanin appear to be *p*-hydroxycinnamates of delphinidin monoglucoside and rhamnoglucoside respectively (Karrer). There is also some evidence of another type of depside anthocyanin in which the acyl group is directly attached to the anthocyanidin molecule and the glucoside group is borne by the hydroxyl of the acid residue.

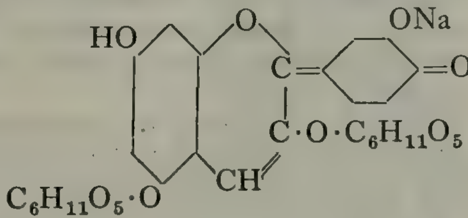
Anthocyanins as Indicators and the Causes of Variations of Colours of Flowers

(With Mrs. G. M. Robinson).

The amphoteric character of the anthocyanins accounts for the exhibition of a wide variety of colours in a range of solutions of graded *p*H, and this method (demonstration), using buffered solutions, can be employed for the characterisation of anthocyanidins and anthocyanins. Under the specified conditions the results are fully reproducible and the *p*H values have been controlled by electrical methods as well as by the use of indicators. Thus, if the *p*H of an acid cyanin solution is increased until the violet tone matches that of an alkaline cyanin solution, the *p*H of which is decreased in order to reach the same condition, then the *p*H of the violet solution will be found to be 7·0–9·0, depending on the shade of violet produced. Cyanin is red in solutions of *p*H 3·0 or less, violet at *p*H 8·5 and blue at *p*H 11·0. The red, violet and blue forms are the oxonium salt (XXIV), the colour-base (XXVI) and the salt of the colour-base (XXVII).



(XXVI)



(XXVII)

(There is no evidence in regard to the assumed position of the quinonoid group and the acidic hydroxyl.)

Now cyanin was isolated by Willstätter and his colleagues from the blue cornflower and from the red rose, and it seemed quite a simple step to assume that the cell-sap in the cornflower was alkaline and that in the rose acid, particularly in view of the fact that the absorption spectra of the coloured aqueous extracts correspond with these conditions.

It has indeed been generally assumed that the indicator colour of the anthocyanin will give a measure of the *p*H of the cell-sap, but unfortunately this method cannot be relied upon for several reasons. In the first place there is a glaring anomaly in the fact that direct measurement by electrical methods (glass electrode as arranged by Mrs. Kerridge) shows that the cell-saps are all well on the acid side of the neutral point. Thus the conventional view for red flowers may well be correct, but some special circumstances must be invoked in the case of blue flowers.

Turning at once to the blue cornflower (the cultivated annual kind), a *blue* filtered extract made with distilled water was found to be sufficiently acid to turn blue litmus red. Using 3 g. of petals in 14 c.c. of distilled water (*p*H 6·3 owing to dissolved CO_2), the *p*H was 4·9. (These quantities were used throughout the experiments and the use of larger relative quantities of the petals did not alter the *p*H appreciably.) Addition of a buffered solution of *p*H 4·4 did not affect the colour, but the colour changed to violet when the B.D.H. Universal Buffer, *p*H 9·0, was added. It was at once apparent that the only simple explanation is

that the cyanin anion is present in a complex form, giving a stable aggregate with a negative charge ; in some way the strength of cyanin colour-base as an acid must be vastly increased.

Some form of colloidal solution was considered most likely to fulfil the necessary conditions, and Dr. Conmar Robinson, of the Chemistry Department, University College, London, kindly examined a filtered, distilled-water extract of blue cornflowers and reported as follows :

'The solution contains ultramicrons easily visible in the slit ultramicroscope, but small enough to be in fairly rapid Brownian movement. Microcataphoresis showed them to be negatively charged. Without more quantitative work it is impossible to say if these particles can represent the bulk of the material present, but this seems probable if the solution is very dilute ; the possibility of observing a colloidal impurity is always a trap. The visibility of the ultramicrons suggests a lyophobic colloid. It is, however, not precipitated even by 2N NaCl, which indicates that a protective colloid is also present.'

Our next step was to attempt the production of blue cyanin sols stable in neutral or weakly acid solution, and some measure of success was achieved, although the solutions are by no means so stable as those from the blue cornflower.

If a little crystalline cyanin chloride is added to boiling tap-water (*p*H 8·0) then the usual violet solution results (see above), the colour being what we consider 'normal.' If, however, the cyanin is triturated in the cold for a minute with the water and gradually heated to boiling with shaking, then a beautiful *blue* solution results. The fact that the same materials can be used to produce two entirely different results shows that it can only be the state of aggregation of the cyanin which can have stabilised the anionic charge and hence produced a blue colour under the conditions that normally produce a violet solution. If very small quantities of cyanin chloride are employed, this phenomenon can be reproduced using distilled water. Willstätter and Everest found that their cornflower extracts contained xylan and other polysaccharides, and we have attempted to produce blue acid cyanin solutions in the presence of various polysaccharides. The addition of dispersed xylan and various kinds of starch, also Agar-Agar, makes the preparation of blue solutions of *p*H about 7·5 a very simple matter (demonstration), but we have not yet found a way of imitating the cornflower solution in respect to its stability at *p*H 5·0.

Probably these colloid associations are much more readily formed at values of *p*H between 5·5 and 6·5, and on the whole the blue flowers have less acid cell-saps than the red flowers. The petals of the rose in contrast with the cornflower constitute an exception (*p*H 5·6), and the following further provisional results may be quoted although no great accuracy can be claimed for a method which involves the destruction of the petals. The pigment of the orange-red polyantha rose 'Gloria Mundi' is found to be pelargonin and the *p*H was 5·5. On the same plant some flowers had reverted to the cyanin type. The red-flowered hydrangea had petal *p*H 3·75, whilst the blue flowers gave *p*H 4·9 ; similarly the red-flowered linum (anthocyanin based on delphinidin) gave petal *p*H 4·6, and the blue variety *p*H 5·9. Blue anchusa, 6·2 ; *Meconopsis Baileyi*, 5·3 (Miss R. Scott-Moncrieff found that blue and violet flowers had the

same petal *p*H); sweet-peas, all about 5·3; delphiniums, 5·6 (most violet shade), 5·8 (most blue shade); clematis (blue), 5·4; viola, 6·2 (blue violet), 6·0 (reddish violet); lobelia (blue), 5·7.

It must be emphasised that these variations of *p*H are quite insufficient in themselves to account for the colour changes and it is evident that the most important single factor for flower colour, given the nature of the anthocyanin, is the question of the condition of the pigment in solution, and it would appear that *all blue flowers are coloured by colloidal solutions of their respective pigments.*

Methods for the determination of the *p*H of the cell-sap of flowers depending on the use of the flower colours as indicators may be sound, but only if it can be guaranteed that the colloidal condition of the pigment solution is not altered by the extraction with the buffered solutions which are employed. In any case, the results bear no relation to the colours observed *in vitro* using isolated anthocyanins and they cannot be transferred from flower to flower; the colour series depends almost as much on the other conditions in the cell-sap as on the *p*H and on the nature of the anthocyanin. Another aspect of *p*H of the cell-saps is that the higher values appear to be associated with the formation of delphinidin derivatives. The remarkable distribution in the tropæolum—Empress of India—is as follows: leaf, delphinidin diglycoside (*p*H 5·6); calyx, cyanidin 3-bioside (*p*H 5·0); flower, pelargonidin 3-bioside (*p*H 4·5). On the other hand three scabious with anthocyanins based respectively on pelargonidin, cyanidin and delphinidin had all the same petal *p*H 5·0.

We have already discussed elsewhere the influence of certain substances termed co-pigments on the colour of anthocyanin solutions; these effects are to be detected in strongly acid solution and the presence or absence of these substances is undoubtedly a factor to be taken into consideration. The extent to which the co-pigment effect is bound up with colloid phenomenon is a matter for future experiment and discussion, but it is convenient to maintain the term co-pigment for the present.

Dr. E. A. H. Roberts has observed the shift of the absorption bands of chrysanthemin and œnin chlorides on the addition of papaverine (strongly blueing effect) and narcotine (weak effect), and correlated this with a corresponding change (lowering) of the distribution number of the anthocyanin using amyl alcohol (demonstration).

It seems clear that papaverine salts and œnin salts combine in solution. The relation between the distribution number of œnin chloride and the concentration of the pigment seems to require the assumption that the molecules of the anthocyanin are associated (2 mols.) in aqueous solution and free in amyl alcohol. Chrysanthemin and idæin behave similarly, also malvidin 3-galactoside. This phenomenon appears to be related to that of co-pigmentation.

The naturally occurring co-pigments include the anthoxanthins (flavone and flavonol saccharides, etc.) and tannins and some efficient substances not yet identified.

The justification for assuming the operation of this factor can best be indicated by an example. Certain herbaceous phlox contain pelargonin, but have a much bluer-red colour than other flowers coloured by this anthocyanin. But the same observation applies to the extract in 1 per

cent. hydrochloric acid, and moreover the presence of much anthoxanthin is noted. Hence, all the circumstances point to co-pigmentation of the pelargonin salt in the flower petal.

Finally, we do not know whether or no traces of iron and other inorganic substances may affect flower colour. In this connection the case of the blue hydrangea is always quoted, and we have observed that when the stalks of red hydrangea flowers are immersed in very dilute aqueous ferric chloride, the flowers slowly become blue. The ashes of many flowers contain 1–2 per cent. Fe_2O_3, and the anthocyanin test for iron is one of the most delicate known.

Summarising, the main factors affecting flower colours are :

(1) The nature and concentration of the anthocyanins and other coloured substances present.

(2) The state of aggregation of the anthocyanin in solution—the *p*H of the cell-sap is one of the subsidiary factors affecting this, and naturally the presence or absence of protective colloids is another.

(3) The presence or absence of co-pigments and, problematically, the effect of traces of iron and other complex forming metals.

Time does not permit me to deal with other anthocyanin types such as gesnerin, the leuco-anthocyanins, the yellow anthocyanin of *Papaver nudicaule*, or the nitrogenous beet-pigment and its analogues ; I will close, appropriately I hope, on an experimental note by attempting a demonstration of some of the tests which we employ for the recognition of anthocyanidins.

(1) The oxidation test—addition of 10 per cent. aqueous sodium hydroxide to a dilute solution shaken with air—petunidin and delphinidin are at once destroyed, the other anthocyanidins are relatively stable.

(2) Extraction with amyl alcohol, addition of sodium acetate and then of a trace of ferric chloride. Characteristic colour reactions are observed, and in particular if cyanidin is present the violet amyl alcoholic solution changes to pure blue in the last stage. Pelargonidin, peonidin and malvidin give no ferric reaction.

(3) Distribution between 1 per cent. aqueous hydrochloric acid and a mixture of anisole (5 vols.) and ethyl *iso*amyl ether (1 vol.) containing 5 g. of picric acid in 100 c.c. Delphinidin is not extracted by the organic layer, petunidin is taken up to a slight extent, cyanidin to a considerable extent, and malvidin, peonidin and pelargonidin are completely extracted if the solution is sufficiently dilute.

(4) Distribution between 1 per cent. hydrochloric acid and a mixture of cyclohexanol (1 vol.) and toluene (5 vols.). Delphinidin and petunidin are not extracted at all ; malvidin gives the organic layer a faint lilac tint ; cyanidin a pale rose tint ; peonidin, and still more pelargonidin, are extracted by the organic layer to a considerable extent.

The deductions are confirmed by a study of the colour reactions of the anthocyanins.

In conclusion I must express my very deep indebtedness to all co-workers in these fields, and especially to Dr. D. D. Pratt, Prof. A. Robertson, Dr. W. Bradley and Dr. A. R. Todd on the synthetic aspects of the work, and to my wife, without whose co-operation a survey of natural anthocyanins could not have been attempted.

SECTION C.—GEOLOGY.

A CORRELATION OF STRUCTURES IN THE COALFIELDS OF THE MIDLAND PROVINCE

ADDRESS BY

PROF. WILLIAM GEORGE FEARNSIDES, F.R.S.,

PRESIDENT OF THE SECTION.

The effort called for in following rock outcrops over hilly country compels the field geologist to think in three dimensions, and, in mountain ground, whatever his first interest, he comes early to a stage when structure gets the lion's share of his attention. The rougher the country, the more trouble is taken to interpret the implications of its surface geometry, until, having achieved a partial solution, the researcher can project his imaginings in depth and predict the locus of the outcrop in another place. In this lies the fascination of our science, and each hill district of Britain is a shrine to some enthusiast who would interpret the anatomy of our ancient alps.

Lowland and coalfield country is less attractive, and it is because he must that the mining geologist and the official surveyor there collects his information. Without some knowledge of its solid geometry no geologist can evaluate a coalfield property, nor should the engineer advise how the development of mineral may proceed. The whole geometry of a coal seam is never known until its wealth is spent, but, pending complete solution, it is possible by stages to project from the fully known to the unknown ; and in the older coalfields, where mining records have been kept, there is such accumulation of local three-dimensional information as can never be made available in the best exposed of mountain ground.

Mine plans are made on a scale so large that, for quick appreciation and interpretation as contributions to regional geology, their records must be reduced to the dimensions of a map. Treated thus over great industrial districts, where hundreds of square miles of several coal seams have been wrought, they afford exact and documented evidence as well of lateral variation of original sedimentation as of the size and form of impressed structures. In detail such information is the stock-in-trade of mineral agents, but in bulk it is rarely considered except by consulting engineers and the maker of the plans.

Coalfields are extensive, their folding broad, and only where relief is exceptional and the rocks diverse does regional structure leap to meet the eye. Coal Measure rocks other than sandstone are soft and weather deeply, so that only where artificial excavations expose fresh material, or where,

by feature mapping of the harder bands, the position of others can be interpolated, can a coalfield map be made from surface evidence. Under such conditions, in country which is marred and scarred by man, it is no wonder that the local amateur is content to collect fossils from spoil-banks or from brick-pits, and accepts from the professional what he is told about the stratigraphy and structure.

Fortunately the officers of the Geological Survey now have full access to mining information, and, as they compile the evidence they are recording it upon the revised edition of the official 6-in. geological maps. As the map sheets are issued their economic usefulness is recognised by the mining profession, but, because of their fullness of detail and because established prejudice regards all coalfield information as uninteresting and dull, the subject matter has not received from other geologists the attention it deserves.

As one whose business it is to teach geology at a university closely associated with industry in the East Pennine Coalfield, I find the call for local application of our science more often concerned with underground geometry than with the composition of the rocks. Therefore, in training men to lead in mineral exploitation, I have insisted that structural geology is a science of measurement, and that the real geology of an area is not fully known until it can be represented by a model true to scale.

From accumulated mining information, or from the modern geological 6-in. maps, it is not difficult to exemplify the shape and size of individual structures, but in presenting a completed picture of a coalfield—even of a district so far exploited as that of Yorkshire—the gaps in present knowledge are so wide that, lacking a working hypothesis to summarise the shapes and distribution of the folds and faults, one must exterpolate, and continually correct approximations as new information comes along. During my years at Sheffield I have enjoyed the sport of correlating nearby coalfield structures on dead-reckoning not less than similar pursuits among the mountains, and it is in the hope that, from a review of obvious trend-lines over a wider area an ordered plan of regional structure may emerge, I have chosen the subject for this address. I am confident that the study of coalfield structures is an open field for the advancement of science, and as mining development proceeds in Coal Measures concealed beneath the newer rocks, successful projection of the buried structures promises no inconsiderable industrial reward.

Where Coal Measures rest conformably on Millstone Grit, the major folds and faults disturbed both formations together, and the unit of structure is therefore greater than the coalfield. Recent investigations, in establishing Upper Carboniferous zonal correlations, have made it certain that a Pennine basin filled with Millstone Grit and Coal Measures extended to the Midlands. The limestone massif of the Peak lines up with Charnwood Forest, the downfold of Cheshire continues into Shropshire ; so for a manageable unit of structure it is logical to take the area within the nearmost outcrop ring of pre-Carboniferous rock. This is the Midland Coalfield Province. It lies all within a circle of sixty miles radius round Buxton. Its bounds are set towards the north by the scarp

of the rigid block of Craven; in the west by the compacted ridges of Denbighshire and the Berwyns; and on the south by the ragged ribs of ancient rock which fringe the Midland barrier of St. George's Land. Towards the east its unknown boundary lies buried beneath thick Permian, Trias and Jurassic rocks, where no man has seen or touched the rocks below the Carboniferous. This Midland Coalfield Province includes the great coalfields of Yorkshire, Derbyshire and Nottinghamshire; of Lancashire and Cheshire, and North Staffordshire; and the lesser fields of North Wales, Shropshire, South Staffordshire and Worcestershire, Warwickshire, South Derbyshire and Leicestershire: and also the proved and probable extensions of these coalfields underneath the Trias. Within this Coalfield Province are nearly a thousand working mines, five hundred of them each employing more than a hundred men in the winning and working of some 120,000,000 tons of coal per year, or more than half the total mineral wrought underground in Britain.

Study of regional structure must begin with notice of the mode of accumulation of the local rocks and of the crustal movements which allowed their accommodation, but in dealing with so wide an area in an address, one cannot do more than mention the distribution and the varying thickness of the sedimentary groups exposed. For details of their constitution and stratigraphy a reference to the *Geological Survey Sheet and District Memoirs*,[1] and for a brief discussion and bibliography the chapters by Garwood, Wright and Kendall in the 1929 *Handbook of the Geology of Great Britain*, must suffice. The only further references noted are to certain recent contributions not included in that extensive bibliography.

The Midland Carboniferous Geosyncline.

At all exposures round the edges of the Midland Province, older beds of the Visean overlap with discordant unconformity against a land topography of moderate relief. Tournasian rocks are only recognised in the deep trough south of the Craven Fault, where, in Pendle and the Craven Lowlands, downward movement began early in the Carboniferous, and

[1] The Geological Survey Publications drawn upon for information herein summarised, include those descriptive of 1-in. maps, New Series, Sheets numbered:

76	Rochdale	1927	126	Nottingham and Newark	1908
77	Huddersfield	1928	137	Oswestry	1928
85	Manchester	1930	138	Wem	1924
86	Glossop	1933	139	Stafford	1927
96	Liverpool	1923	141	Derby and Burton-on-Trent	1905
100	Sheffield	1914	142	Melton Mowbray	1909
108	Flint	1924	152	Shrewsbury	1933
110	Macclesfield	1906	153	Wolverhampton	1929
112	Chesterfield	1929	154	Lichfield	1926
113	Ollerton	1911	155	Atherstone	1910
121	Wrexham	1927	156	Leicester	1903
123	Stoke-on-Trent	1924	158	Birmingham	1924
125	Derby and Wirksworth	1908	169	Coventry	1926

together with those relating to the parts of 1-in. maps, Old Series, Sheets numbered: 53, 60, 61, 72, 73, 80, 81, 82, 87, 88, 89 and 90, which have not been recently revised.

was progressive until 10,000 ft. of pre-Coal Measure sediment was accommodated. Three thousand five hundred feet of alternating Visean shales and reef knolls in this mid-Pennine trough contrast sharply with the equivalent 400 ft. of Great Scar Limestone and overlying shale deposits on the adjoining Ingleborough block.

Across North Wales and the southern Pennine district, Visean sediments are mainly bands and banks of shallow-water limestone, 1,800 ft. thick at the head of the Vale of Clwyd, and a little more in the open section along the Wye Valley in Derbyshire. Locally in the High Peak district, and to a much greater extent where pierced by borings in search of oil beneath the Derbyshire and Staffordshire Coalfields, these limestones are interstratified with submarine eruptive products. Towards the Midlands the amplitude of Visean movements was less, and as the marginal beds of limestone lap against St. George's Land, though all the subdivisions are represented, their total thickness has diminished to about 1,000 ft. on the northern flanks of Charnwood, and to less than 300 ft. east of the Wrekin towards the Severn Valley.

Visean deposits of the Midland Province end with shallow-water limestones containing the D3 facies fauna, which may or may not belong to one horizon. At some places cherty beds pass up to earthy 'black beds' and bituminous shales. Elsewhere the last of the grey limestones are impersistent shell banks and limestone breccias, and there is striking evidence of an interformational non-sequence. With application of modern zonal methods to the faunas of the shales which overlie the limestones, it has been recognised that in Pendle, between the topmost Visean limestone and the beds with faunas identical with the lowest Edale shales of Derbyshire, at least 3,000 ft. of land waste was accommodated. Lower Lancastrian shales and grit bands are 2,000 ft. thick in Staffordshire,[2] but have not been recognised in the Derwent Valley, so in Peakland the non-sequence may become an unconformity. Transgression near the same horizon has been followed along the edges of the Craven-Ingleborough block, and the relation of the Holywell shales to the underlying cherts and Cefn-y-fedw series in North Wales requires a similar explanation. These evidences of structural disturbance are not regular, and whether we regard them as marking areas of local uplift, or attribute the non-sequence to cessation of downward movement, we must recognise that they coincide with arch folds which now dominate the local structure.

Most important of the early Lancastrian upfolds, from the point of view of coalfield distribution, is the limestone plateau outcrop, the 'massif' of the High Peak of Derbyshire.[3] Its margins have steep dips, but though its place is the north-west extension of the Charnwood Pre-Cambrian platform, there is underground evidence that its topmost limestones extend widely in all directions beneath the overlying shales,[4] and it cannot be accepted either as reef mass or as a pre-Lancastrian horst.

[2] S. W. Hester, 'The Millstone Grit Succession in North Staffordshire,' *H.M.G.S. Summary of Progress for 1931*, Pt. II, p. 34 (1932).

[3] W. G. Fearnsides and others, 'The Geology of the Eastern part of the Peak District,' *Proc. Geol. Assoc.*, vol. 43, p. 152 (1932).

[4] T. Sington, 'The Search for Petroleum in Derbyshire now in progress,' *Trans. Inst. Min. Eng.*, vol. 57, p. 25 (1919).

Moreover, its monoclinal edges are plicated by pitching cross-folds, on whose arches are the reef knolls and beds of limestone breccia, and in whose troughs there is the appearance of conformity from cherty limestone to Lancastrian shales older than those which are continuous over intervening arches. These cross-folds have persisted as belts of instability throughout and beyond the period of the Carboniferous. Their extended axial lines are marked by rapid pinching out of sandstones of the Millstone Grit deposits, and they line up with the steep-sided anticlines and synclines of the Derbyshire and Midland Coalfields. The most northerly of these curving cross-folds terminates and contains the High Peak limestone area, and beyond it there is no evidence of pre-Lancastrian uplift of any central Pennine fold.

During the later Lancastrian or Millstone Grit period, and on throughout the Coal Measures, negative movement, though progressive, was punctuated by frequent delays. Sediment was delivered to Yorkshire in such quantity that it could not be accommodated until regional settlement had made its place. During the waiting periods therefore it drifted on towards Cheshire and built its lenses on the front of the growing delta. As sinking proceeded there was agitation in the shallows, and coarse material was entrapped in deepening troughs. Coarseness of sediment in such measures, though it must always be an index of the velocity of the inwash current, can in no wise be accepted as a criterion of proximity to a shelving shore.

Lancastrian sediments are thickest north of the Lancashire Coalfield, where more than 5,000 ft. of shales and grits were accommodated. The Millstone Grit divisions lose thickness southward round about the Peak district, but in Staffordshire the bore-hole at Rownall Hall, started below the Middle Grits, had not reached limestone at a depth of 2,700 ft.[5] Against the encircling fold which ends the limestone outcrop of the High Peak at Castleton, lenses of sandstone, which are exceptionally strong in the 'edges' of Kinderscout, lose half their thickness. We have no proof that P. or lower E. beds were ever deposited over the High Peak district, but mineral constitution seems to show that the coarsest Middle Grits were persistent from the Derbyshire Edges east of the Derwent to the Roaches of Staffordshire. Within the East Pennine Coalfield, deep borings indicate a wedging out of the whole series south-eastwards, from 1,500 ft. thick at Renishaw to less than 300 ft. at Kelham. The available records are all from trial oil wells in anticlinal areas, and there is evidence of grits and shales outcropping north-west of Charnwood, and Lower Lancastrian E2 shales persist beyond the Hathern boring.[6] South-westwards across Lancashire the advancing Millstone Grit delta did not reach North Wales, and in 400 ft. of Holywell shales all the Lancastrian zones are represented.

Despite pulsatory and progressive subsidence, the whole South Pennine area was filled and levelled to a plain before the period of the Millstone Grit was ended, and the latest G. marine band spread over and drowned

[5] H. P. W. Giffard, 'The Recent Search for Oil in Great Britain,' *Trans. Inst. Min. Eng.*, vol. 65, p. 221 (1923).
[6] 'Wells and Springs of Leicestershire,' p. 99. *H.M.G.S. Mem.* (1931).

a coal seam which extended across the Midland Province. This is the famous Alton, Halifax Hard, Bullion, Upper Foot, or Crabtree Coal Marine Band. Near the top of the Productive Measures the Mansfield, Sharlstone, Dukinfield, or Speedwell Marine Band is similarly continuous in all Pennine coalfields, and the thickness of measures between the two affords a trustworthy indication of the aggregate amplitude of negative movement in the various districts during the Coal Measure period. By measurement of this distance we recognise in South-east Lancashire, where the intervening thickness exceeds 4,000 ft., the regional centre of the Coal Measure collecting dish. About that centre in all directions the thickness of sediment accommodated diminishes to 2,000 ft. in less than 50 miles. By plottings of isohypses of sediment between successive coal seams, we can, with labour and persistence, prove the local variations in the amplitude of depression to any degree of accuracy we choose. Each coal seam grew at water-level during a waiting period, but individual coals are not sufficiently persistent, and only exceptional groups of coals have a coalfield-wide distribution. For comparative studies of variations of the rate and amount of movement as between one coalfield and another, we therefore depend upon the modern method of identification and correlation of Coal Measure horizons by interstratified non-marine lamellibranch zones.[7]

Consideration of the lowest group, the Halifax Coal Measures, shows them thickest in North or Central Lancashire, where also the Millstone Grits are thickest. There more than 1,000 ft. of Coal Measures underlie the Arley Mine. Equivalent measures [8] at outcrops in Yorkshire, Derbyshire and North Staffordshire are less than half that thickness. The Ovalis zone, 600 to 1,000 ft. thick in Yorkshire, is more than 1,500 ft. thick in Central Lancashire. It thins eastwards across Yorkshire, and to the south-east across Derbyshire to Nottingham. The Modiolaris zone, the main coal-bearing belt, maintains through Yorkshire and Derbyshire a wonderfully constant thickness, about 1,000 ft., along the strip of country where Park Gate and Barnsley coals are wrought. This zone is fully 1,200 ft. thick about Oldham, but thins southwards through Cheshire into North Staffordshire, and more rapidly westwards across Lancashire.

Variation of thickness in the Similis-Pulchra zone is much more rapid. This zone attains its maximum thickness in the Pennines south-east of Manchester. East of the Pennines a plotting of isohypses for the sediments between the Barnsley Coal and the Mansfield Marine Band proves a thinning from over 1,000 ft. at outcrop to less than 500 ft. in the most easterly of working pits, which rate of thinning, if continued, would give the Barnsley Bed the Mansfield Marine Band for its roof within a very few miles east of the Trent. Beds between the Mansfield and the Shafton

[7] D. A. Wray and A. E. Trueman, 'The Non-marine Lamellibranchs of the Upper Carboniferous of Yorkshire and their zonal sequence,' *H.M.G.S. Summary of Progress for 1930*, Pt. III, p. 70 (1931).

[7] A. E. Trueman, 'A suggested correlation of the Coal Measures of England and Wales,' *Proc. South Wales Inst. Eng.*, vol. 49, p. 63 (1933).

[8] D. A. Wray, L. Slater and G. E. Eddy, 'The Correlation of the Arley Mine of Lancahsire with the Better Bed Coal of Yorkshire,' *H.M.G.S. Summary of Progress for 1930*, Pt. II, p. 1 (1931).

Marine Bands in Yorkshire and Nottinghamshire similarly wedge out rapidly towards the east and south. Across Lancashire the westward diminution of thickness is continuous. About Oldham the Dukinfield Marine Band is 1,250 ft. above the Furnace Coal, whereas at Tyldesley its place is less than 800 ft. above the Rams. In the trough of North Staffordshire near Tunstall the Speedwell Marine Band is 1,400 ft. above the Ten Foot Coal, but there is rapid wedging out of measures both towards the western anticline and towards the south.

The Pottery Marl and Blackband Ironstone series of the A. Phillipsii zone in North Staffordshire may be 1,200 ft. thick. They pass up into an equal or greater thickness of red and mottled Etruria Marls. In South-east Lancashire 1,800 ft. of grey measures, including the Bradford group of coals, overlie the Worsley Four Foot (which may be the Shafton Coal of Yorkshire), and underlie the variegated marls and limestones of the Ardwick series. East of the Pennines Etruria Marls are preserved only in the centres of the synclines. Beneath them in South Yorkshire, above the Shafton Marine Band, grey beds, mostly sandstones, are 1,200 ft. thick, but between Mansfield and Nottingham equivalent measures thin south-eastwards to less than 300 ft.

Because of cumulative displacement by negative pulsations, and because the supply of sediment was never-failing, Coal Measures in the great coalfields which flank the southern Pennines are an expanded series. Southwards along the margins of the Province less accommodation was provided, and Productive Measures taper out against the Midland barrier of St. George's Land. Zonal correlation by non-marine lamellibranchs is not yet available for the Thick Coal district of South Staffordshire and Warwick, and the best suggestion for correlation of horizons is by the tracing of coal seams in relation to occasional marine bands. Away from the Pennines, the G. or Alton Marine Band has not been proved beyond South Derbyshire, where it lies about 1,000 ft. below the Main Coal, and has below it Millstone Grit. A more persistent marine band overlies the Main Coal in Leicestershire and the Seven Foot Coal in Warwickshire, and this may be the White Stone Band below the Heathen Coal of the Black Country and the Pennystone of Coalbrookdale. If one may guess that it is also the Speedwell Band of Staffordshire, its position within 200 or even 100 ft. above the pre-Carboniferous bed-rock of the Thick Coal districts is evidence that these shores of the Midland barrier did not come within the belt of sedimentation until a late stage of the infilling of the Coal Measure basin. If it represents the marine band above the Seven Foot Banbury, at the base of the Modiolaris zone, it must indicate that the creeping transgression which brought these beds across the upraised edges of Midland Visean and Lancastrian deposits was inordinately slow. The thickness of the Productive Coal Measure sediments accommodated in the Midland coalfields is from one-tenth to one-fifth of that disposed in the Central Pennine area of North Staffordshire. Conditions must have been strangely static for a very long period when the Thick Coals were growing, but within that series there are no more appearances of stratigraphical discordance than where equivalent sediments are thick.

Increase of the thickness zone by zone towards the centre in the southern Pennine area may be accepted as evidence of progressive geosynclinal development and its differential deepening. There is compounded with this regional settlement increase of thickness in troughs and thinnings towards the crests of local folds. Probably the best-known coalfield example of such local variability is the Potteries syncline and the adjoining Western or Rearers anticline of North Staffordshire. There from crest to trough the total thickness of Productive Measures underneath the Red Beds varies within two miles from 2,500 to 3,500 ft. Individual coal seams continue across the whole coalfield ; marine bands and shales with non-marine lamellibranchs are similarly persistent, and the variable component in the measures is the coarse land waste which accumulated in thicker and more numerous sandstone lenses towards the centre of the trough. There is no evidence that the crest of this fold was so uplifted that some beds might have been denuded ; and it follows that the development of the anticline was by differential sinking of the lateral troughs. As with the regional tilting towards the centre of the geosyncline, so in this local folding the rate of change of thickness was slow until the more important coals had grown (Ovalis and Modiolaris zones), but becomes increasingly differential through and towards the later part of the Similis-Pulchra zone.

The Horseshoe anticline in the North Wales Coalfield has a slightly different history. It too was sinking more slowly than neighbouring areas when measures containing the Lower Coal series were deposited across it. Thereafter, though it continued to receive a share of sediment, it maintained a line of shoals which acted as a barrier and diverted the flow of sediment, so that there is striking dissimilarity between the Bulkeley Fireclay series formed in the troughs of Flint, and the Upper Coal and Cefn Rock series deposited contemporaneously in Denbighshire. At its northern end along the Dee estuary, before the deposition of red Upper Coal Measures over it, some hundreds of feet of measures were denuded from its broken and upraised crest. Series of wash-outs in coal seams under sandstones in the Flintshire syncline are interpreted as erosion features produced by stream-courses directed longitudinally by the folding of the trough.

In Coalbrookdale, Productive Measures, including some hundreds of feet of measures newer than the Pennystone, were sharply folded and faulted by posthumous disturbances of pre-Carboniferous post-Silurian folds. These movements were mainly completed and the anticlinal crests denuded before the overstep of Upper Coal Measures, which is the unconformity of the Symon ' Fault.'

Statistical studies of colliery records within the open folds of Yorkshire are bringing evidence that above the Barnsley Coal, and especially towards the top of the Similis-Pulchra and through the lower parts of the Phillipsii zones, the total thickness and the proportion of sandstone in the sedimentary column increases progressively to a maximum over the deepest parts of the Frickley and Maltby troughs.[9] There is no suggestion of

[9] ' Sections of Strata of the Yorkshire Coalfield,' *Midland Inst. of Min. Eng.* (1927).

any emergence of the Don Valley fold before the Red Beds were deposited over it, but both in Yorkshire and in Derbyshire, where the folds are steeper and narrower, it is probable that by the time the latest coal streaks of the A. Phillipsii zone had accumulated, the workable coals lay many hundreds of feet deeper in the synclines than over the anticlines between.

The latest grey beds of the Phillipsii zone pass up by alternations into the Red and Mottled series which for convenience is taken as the lowest division of the Upper Coal Measures. These variegated and ill-stratified Brick and Tile Marls (Etruria Marls) are over 1,250 ft. thick in the trough of the Potteries Coalfield, and as the Ruabon Marl group in Denbighshire their thickness is hardly less. Of the equivalent Ardwick group of the Manchester syncline, over 1,000 ft. remains below the Collyhurst Sandstone. At Farnsfield in Nottinghamshire, some 600 ft. of variegated beds are preserved beneath the Permian in the deepest part of the East Pennine basin. In South Staffordshire, the thickness of the Marl group is very variable, from 800 to 150 ft. within two miles, and there is evidence that with redisturbance of local folds across the Black Country, trough-like areas were developed in which deposition kept pace with the sinking of the floor. In Warwickshire and in Shropshire, and in the south of South Staffordshire, the Marl group overlaps the Productive Coal Measures against the shores of islands, whose waste provided the fragments which compose the Espley Rocks.

The Newcastle-under-Lyme group of the Potteries is 600 ft. thick. Its variegated grey and green beds mark a temporary late return to normal Coal Measure conditions in the south-west Midland area. As the Halesowen Sandstone group of South Staffordshire and Warwickshire, and the Coalport group of Shropshire, its component members thin as they overstep towards the south, and it rests with slight unconformity on the Old Hill Marls or older rocks below.

Over the eastern part of the Midland Coalfield Province, the stratigraphical record of the early development of structures ends with the deposits of the A. Phillipsii zone. In the south-west, red and purple marls, sandstones and conglomerates, deposited in reasonably strict conformity upon the latest coal-bearing series, carry on the history of settlement and contemporaneous filling of a land-locked basin to a later stage.

In North Staffordshire some 700 ft. of red, purple and grey marls and sandstones form the Keele group. Over the Warwickshire Coalfield and all round the South Staffordshire Coalfield this group maintains its thickness, but in Shropshire it tapers out south-westwards as it overlaps beyond the coalfields against the edges of older land. Upwards it passes into the calcareous Enville group of Staffordshire or the Corley group of Warwickshire, with interstratified lenses of conglomerate, and in the higher parts has great wedges of breccia, scree or torrent-borne products derived from neighbouring Lower Carboniferous, Silurian, Cambrian or Pre-Cambrian outcrops upraised towards the south. In southern Warwickshire,[10] the thickness of the extended Corley group is not less

[10] F. W. Shotton, 'On the Geology of the Country around Kenilworth,' *Q.J.G.S.*, vol. 85, p. 170 (1929).

than 3,500 ft., and along the Severn Valley the Clent Breccias are also thick. Northwards and westwards, as the breccia beds tail out, the group becomes difficult to separate from calcareous Keele beds with which they are included in the 2,000–3,000 ft. thick Erbistock series of Denbighshire.

The accommodation of such thickness of Upper Coal Measures over the Western Midlands necessitated the shifting the Pennine geosynclinal centre towards the south. To what extent the uprising of the Derbyshire High Peak area was contemporaneous, is not known, but pebbles in Midland conglomerates have not been traced to any Pennine source. In the Ingleton Coalfield the highest Red Beds with bands of Spirorbis limestone are associated with brockram scree deposits, and by this stage uplift to the north and denudation of the escarpment of the Craven Faults had there exposed the Lower Carboniferous.

In the Concealed Coalfield of Yorkshire and Nottinghamshire basal Permian transgresses 5,000 ft. of folded Coal Measures. The simple geometry of the floor on which the Permian rests shows that, following the storm of crustal movements, the cycle of denudation was completed. The regular eastward slope of that buried peneplain from Tynemouth to Nottingham is proof that that side of the Pennines was already consolidated as a structural unit, which, rippled by gentle swelling of the underlying cross-folds, and cracked a little by rejuvenated coalfield faults, has since been tilted as a whole. Such later displacements as, east of Leeds and about Nottingham, have also cut the Trias, are of amplitude insufficient to distort the structural pattern, which, born before the end of the Visean, developed during the Lancastrian and Productive Coal Measure period, attained maturity when the Red Beds of the Midlands were being deposited, and was dissected and planated before tilting and regional settlement depressed it to receive the sediments of the Magnesian Limestone sea.

West of the Pennines, the Collyhurst Sandstone rests with sharp discordance upon the tilted Ardwick group, and westwards transgresses 3,800 ft. of underlying Productive Coal Measures. Its thickness alters abruptly, sometimes by hundreds of feet, at the crossings of important faults, and its disposition suggests accumulation in the fault scarp hollows at the foot of the upraised and faulted Pennine and Rossendale anticlinal ridges. The Manchester Marls above it are displaced, but not otherwise affected by faulting which also cuts the Trias. They contain a fauna correlated with the Lower Magnesian Limestone, and pass up by transition into the Bunter Sandstone of the Cheshire Basin.

South of the Pennines the evidence of post-Carboniferous chronology is mainly buried under Trias, which banks against a land surface composed of every kind of older rock. Each exposed Midland coalfield is a dish or dimple in an upraised horst, bounded by faulted folds of variable pitch, which are axially convergent on the Coal Measure geosynclinal centre west of the Peak near Manchester. In middle limbs outside the lateral crests are powerful but discontinuous boundary faults, flanking the Trias-filled deep depressions which contain concealed coalfields. These boundary faults are late Carboniferous structures which displace alike all members of the Productive and Upper Coal Measures, to and including the Keele

group, and much of the Corley and Lower Enville beds. Several of them line up with older breaks in the pre-Carboniferous platform, and many are known to have continued their displacement during and after the deposition of the Trias. Marl conglomerates towards the top of the Upper Coal Measures suggest contemporaneous movement of neighbouring faults, but pebble and breccia beds are torrent-borne from southern lands, and the main displacement of both folds and faults is later than the Upper Coal Measures deposits. Possibly the latest Enville, Corley and Erbistock beds are contemporaneous with some Magnesian Limestone, but proof is lacking, and the steady structure demonstrated in the basal Permian peneplain is not yet recognised west of Derbyshire.

There being no fossils in the Trias of the Midland Province, the age of movements affecting it cannot be checked by zoning. Wedges of Bunter Sands and Keuper Marls in Nottingham overlap the wedge of Magnesian Limestone to rest on Coal Measures and older rocks in Derbyshire and Leicestershire. Tilting continued with sedimentation, and east of the Pennines the sloping surface of concealed Coal Measures is buried under a thousand yards of Permian and Trias within a few miles east of the Trent. The great basin of Cheshire with its salt beds, and Shropshire with its patch of Lias, downfolded as it filled. Its depth and what lies under it are matters for conjecture, but the Plumley borehole pierced 2,500 ft. of Keuper, and Bunter Beds at Heswall have been proved 2,200 ft. thick. The turn-up of Trias to the western anticline of Staffordshire, and the Red Rock Fault of Cheshire, is evidence of further substantial settlement, since the deposition of the down-tilted beds.

The Trias basin of Staffordshire sagged as a duplex trough on either side of the faulted saddle of the Black Country. The western downfold, like the Shropshire basin, is edged about with latest Carboniferous Red Beds, and within it conformable passage between the two formations is not impossible. In the depression to the east of Stafford, the Chartley boring passed through 2,000 ft. of Trias, and outliers of Rhætic lie further to the east. From the north part of this basin fingers of Bunter extend along steep-sided valleys scored in the southern ending of the Pennines. The edges of the Leicestershire platform are also ragged; and against and over them Bunter is overlapped by Keuper, which completes the transgression of Trias across the coalfield synclines of Warwickshire and Leicestershire, and overtops the sharp, upstanding peaks of Charnwood Forest. That core of Pre-Cambrian in Charnwood, along with the western portion of the Pennine block, must have been elevated as the Nottinghamshire, Staffordshire and Cheshire Trias basins were being filled. Eventually all elevations, cluttered up in their own debris, were buried under the great bulk of material washed to the Midlands by torrents or wind-swept from the foothills of the great Hercynian Chain. By the time the desert deposits of the Keuper were covered by the Rhætic Sea, the whole Midland Province had been upgraded to a plain.

Wherever there is exposure of bare rock, and diversity of rock character to show it, there is evidence that the even lie of Trias and post-Triassic rocks has been disturbed by later movements, but in the Midland Coalfield Province, except for certain arcuate groups of east-west faults which cross

the Pennines, and a few north-west fractures occupied by Tertiary dykes, the disposition of those faults agrees so closely with the trend of older structures that all may be interpreted as posthumous adjustments of the underlying floor. The later structural history of the Midland Coalfield Province is not documented by its own deposits, and we may leave the stratigraphical study of its development at this stage.

Fold Distribution.

A striking feature of the small-scale geological map of England is the alignment of the coalfields in east-west rows. The coalfield of South Wales is an east-west downfold in the forefield of the Hercynian mountain chain, and it has been assumed that, beyond the upfold of the Midland or Mercian Highland barrier, the Midland group of coalfields occupies the following trough. The history of coalfield evolution outlined above tells us that the Midland barrier was already a structural unit when Carboniferous rocks were laid against it. There is no suggestion of natural separation of the southern Midland coalfield district from the greater coalfields around the southern Pennines. The filled Carboniferous geosynclinal basin, subsequently everted, must for structural purposes be considered as a whole. The wide pre-Permian break between its Yorkshire-Lancashire edge and the downfold containing the Durham-Cumberland alignment also may be a Hercynian master-upfold, but pending analysis of its structures, it were well to suspend judgment.

With the idea that east-west downfolds across the Midlands are Hercynian, goes the notion that the Pennine 'backbone of England' is a complementary north-south cross-fold; but there is divergence of strikes within it, and as we know that the limestone district of Derbyshire was upstanding at the time of the pre-Lancastrian unconformity, it is difficult to accept it as other than a rejuvenated and accentuated group of older structures.

Having looked for and failed to recognise the leading lines of the supposed Hercynian chessboard in the arrangement of coalfields within the Midland Province, I long since suggested [11] that the upstanding High Peak massif of limestone of Derbyshire is founded upon an extension of the pre-Cambrian platform of Charnwood Forest, and I would now maintain that contention by a demonstration of the distribution of its supporting folds. To this end I have had compiled, first by pantographic reduction from the 1-in. geological maps to the $\frac{1}{4}$-in. scale, and then by photography and retracing, the diagram (Fig. 1), on which are plotted in correct relationship all fold-lines which the officers of the Geological Survey have located and indicated on the published maps.[12] The result is striking, both in confirming the alignment of the High Peak plateau with Charnwood Forest, and in its emphasis of the persistence of other ridge lines from the

[11] W. G. Fearnsides, 'Some Effects of Earth Movement on the Coal Measures of the Sheffield District,' Pt. II., *Trans. Inst. Min. Eng.*, vol. 51, pp. 445–450 (1916).

[12] The laborious work of this reduction was undertaken by William Pulfrey, M.Sc., Ph.D., research worker in the Department of Geology at Sheffield University, to whom I return grateful thanks.


FOLD AXES
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Fig. 1

scattered outcrops of Lower Palæozoic formations around the Midlands in later foldings of the Carboniferous rocks. There is no chessboard or other interlacing of the folds. The folds are congruent, curving, clustered or divergent; acute and often steeply pitching where there is great change of stratigraphical level, but ill-defined and widely separated where the troughs are broad. It is difficult to perceive how, in yielding under unilateral stress, sheets of new-made Coal Measures could have wrinkled in such forms. It seems more likely that, like blankets on the bed of a restless sleeper, they have heaved and buckled in accommodating themselves to the movements down below. It is recognised that in the contemporaneous filling of each deepening syncline, as old folds tightened differences of rigidity between adjoining areas must have been perpetuated, and thus, whatever crustal thrust has later disturbed the underlying Lower Palæozoic platform, could not do other than exaggerate existing strains. Established lines of yielding have been from age to age rejuvenated, but the plotting of fold-lines has discovered no local bending structures in the Midland Coalfield Province, which can be determined as begun by late Carboniferous movements, or as having adopted a novel impressed Armorican or Hercynian trend.

To the coalminer the unit of structure is the coalfield—a group of several down-folds forming a distorted trough or synclinorium. For the geologist arches are more conveniently described as individual structures. The complex ridge of Charnwood pitches down north-westward under the Trent Valley, beyond which, by Ashbourne, folds rise to culminate near Buxton. Northwards the Pennine anticlinal crest droops down some 2,000 ft. under Kinderscout. Thence it continues almost on level course along the mid-Pennine ridge of Millstone Grit, and curves a little towards the east to Keighley. At intervals of a few miles the High Peak ridge throws off, most noticeably towards the east, trailing transverse folds, which spread fanwise across the Derbyshire Coalfield. These transverse folds are sinuous in plan, and variable both in amplitude and pitch. Locally intensified, they bring up the limestone inliers of Crich and Ashover, and the cracked domes which were pricked for oil, successfully at Hardstoft, but unsuccessfully at Brimington, Renishaw, Ridgeway and Ironville. Never straight, their direction swings round in reversed ' S ' bends almost through a quadrant. To the north in the moorland country the transverse undulations are less acute, their crest-lines swing first northwards, and then eastwards and a little southwards, as they lose themselves in the broad trough of the Yorkshire Coalfield.

On the west side of the Pennine-Peak-Charnwood ridge-line the change of geological level is rapid. In Leicestershire the Thringston Fault puts Coal Measures against Pre-Cambrian, and with the two or three sharp infolds of minor coalfields west of Buxton, the High Peak adjoins the Cheshire Plain. This last great downfold, however, is not a simple structure. To it, as to a neck, the extensions of the folds between Charnwood and the Longmynd come to meet and join. The triangular form of the North Staffordshire Coalfield demonstrates the gape of the virgation within whose southward opening rise the ribs which are the Productive Coalfield of the Midland district. The plotting shows that

each major fold axis in the Midlands, if extended northwards, would come to Manchester. Within the convergence the pitch of folds is somewhat variable, but there is no evidence of interweaving, or rise and fall by cross-folding, which can be interpreted as compounding with broad east-west Hercynian folds. North and west of Buxton folds in the Millstone Grit country swing southwards round the High Peak ridge, and there is rude symmetry of fold distribution in Staffordshire and Derbyshire about the north-west line of the extended Charnian axis.

Across the Manchester Coalfield the broad trough is cut to ribbons by north-west faults, which break the measures, as, bending, they dive towards the Cheshire Plain. Minor folds alongside major faults have axes which diverge westwards from the Pennine fold. The east-west Rossendale anticline of mid-Lancashire is so broad a swell that, as with its neighbour the even broader Cheshire basin, the location of its merging in the Pennine fold is ill-defined. The sharp monocline which makes the Pennine crest near Todmorden bends round to the east towards Keighley, and the triangular trough of the Burnley Coalfield is evidence that the Charnian midrib of the South Pennine structure, which is more or less continuous from Leicestershire, has here ended.

Beyond the North Lancashire Coalfield the trend of sharp folds in the Craven lowlands is north-easterly. They swing to the eastwards through Skipton as far as Leeds, to follow and define the northern edge of the Yorkshire Coalfield. From their divergence to the westwards it is evident that the Craven lowlands and North-west Lancashire is a structural unit quite distinct from the North Lancashire Coalfield, and there is similarity of structure between this Pendle-Bowland area adjacent to the Craven Faults and the fold virgation in North Staffordshire.

The structure of the North Wales coalfield country north-west from Shropshire has lately been discussed by officers of the Geological Survey, and folds affecting Carboniferous rocks are interpreted as due to tightening and adjustment of structures already developed in the Lower Palæozoic rocks.[13] Whether or not the upstanding mass of the Longmynd has protected from Hercynian fold invasion the plains of Southern Cheshire, resultant movement in Flint and Denbighshire has produced the horse-shoe anticlines whose range is more or less parallel to the Lower Palæozoic outcrop, and in groups separated by great tear faults they bulge eastwards upon the Cheshire Plain.

Fault-Pattern.

Following the consideration of fold axes, a similar plotting and reduction has been made [14] of the distribution and alignment of recorded faults, and the intricate patterning of Fig. 2 results. From comparisons of super-posed diagrams, as first reduced to the $\frac{1}{4}$-in. scale, it is clear that the dominant families of faults follow the limbs of folds, but that they sweep in curves of radius larger than the axial curvature of folds. No fault

[13] C. B. Wedd, 'The Principles of Palæozoic and later Tectonic Structure between the Longmynd and the Berwyns,' *H.M.G.S. Summary of Progress for 1931*, Pt. II., p. 1 (1932).

[14] Also by Dr. Pulfrey.

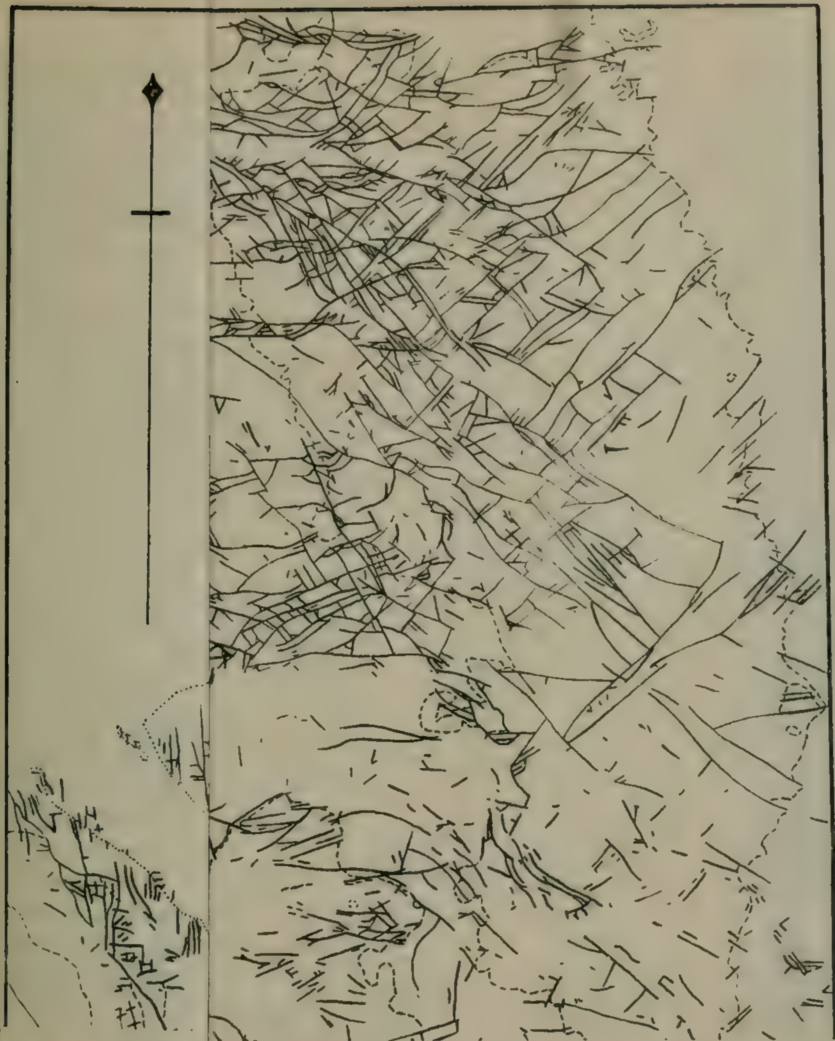

Fig 2

outcrop is really straight or continuous for many miles, but major fault-lines curve with a radius which is often greater than ten or even twenty miles. Leading faults, changing direction, give off tangential branch faults or receive tributaries which trail in at angles less than 45°. Transverse faults are usual across the troughs of pitching synclines. Where transverse and longitudinal faults cut the country into more or less quadrangular blocks, faults which are ending bend to meet the curve of the persistent fault.

Large faults are generally associated with change of dip or change of strike of strata, and are therefore inconstant in their throw. Large faults frequently occur *en echelon* in the middle limbs or sides of troughs, where their direction makes a small angle with both the strike of the measures and the pitch axis of the fold. Mostly faults tend to converge towards a rise of pitch. Transverse faults sometimes displace the crests of anticlines, but are of greater importance as they reduce the effect of pitch along the synclines. Most transverse faults bend and lose their throw as they approach the steeper middle limbs of folds, and change the curvature of their direction as they pass from anticline to syncline.

Certain groups of complex or paired trough fractures sweep in discontinuous arcuate curves across the Midland Coalfield Province on a radius as great as fifty or sixty miles. These are not obviously related either to the trend of noticed folds or to the longitudinal or transverse fault breaks, with some of which they join. Of them the most extensive system follows a rude semicircle through the North Lancashire and East Pennine Coalfields from Accrington, by Todmorden to Huddersfield and Sheffield, and across Derbyshire to the Dukeries. If it is continuous with the fault belt which from Blackburn extends to Wigan and St. Helens, it may encircle the Cheshire Basin.

Other fault groups which bend round the High Peak of Derbyshire also cross the Pennines. These carry on through the Derbyshire and Nottinghamshire Coalfield, and may encircle the platform of Charnwood Forest. The most northerly of this group traverses the Pennines from Rochdale to the Calder Valley, and intercrosses with the Todmorden-Sheffield disturbance in the Rishworth Moors. A more southerly group close to the limestone boundary at Castleton passing by Holmesfield and Chesterfield to the south of Mansfield, crosses and recrosses the reversed 'S' bend of the Brimington anticlinal axis.

In Flint and Denbighshire also, arcuate groups of fractures likewise slice across the horseshoe fold axes. These are circumferential to the Silurian buttress of Snowdonia. Where, in the Trent Valley, Trias is banked against the southern ending of the Pennines, broadly arcuate east-west fractures cut directly across the Pennine Carboniferous folds.

Appreciation or description of coalfield fault pattern is difficult except by diagram, but regional trends change gradually, and within the Midland Coalfield Province the only apparent discontinuities are gaps or obscurities due to lack of information. Drift obscures the fault outcrops in the Trias country, and Carboniferous, deep bedded under Trias, reveals its structure only as the coal is worked.

The criss-cross fault arrangement of the Yorkshire Coalfield has been

compared by Professor Kendall [15] to the crack lattice produced by twisting slabs of glass, and the differential lifting of the Pennines was suggested as the agency of the twist. The analogy is a good one in that it reminds us that the simplest kind of stress may in a single operation by resolution produce the diamond fault-block pattern. North of the Don the most persistent faults are longitudinal in the flanks of the wide West Yorkshire trough, wherein they converge and anastomose, with rise of pitch north-westward. In this area transverse faults preserve an almost constant north-easterly direction. Most of their movement was pre-Permian, but some have since increased their displacement, and certain east-west faults which are longitudinal in the flank of the northern boundary anticline extend into the Trias. There is to the north of the Don anticline, near Rotherham, one area twenty square miles in extent without a charted fault. That, however, is exceptional, and triangular or quadrangular blocks, of a few score acres to three or four square miles, are characteristic of the Yorkshire Coalfield.

In Derbyshire, and with less certainty in Nottinghamshire, the fault pattern is recognisable as an extension of that better defined in Yorkshire, but local folds of variable pitch dominate the Derbyshire structure. Faults following the general north-west elongation of the coalfield basin join with the arcuate groups, and bend eastward to cut across the limestone area of the High Peak. In Derbyshire there is no strong development of north-east fractures, and the few faults which break the Permian outcrop south of Sheffield are either north-westers, or in the south, near Nottingham, where they become important, members of the east-west arcuate system of the southern ending of the Pennines.

In Lancashire transverse faults have cut the coalfield into boat-shaped strips which taper sharply where neighbouring members of the same fault series join. About Manchester the master fractures traverse steep measures in the trough of the wide syncline as it pitches to the Cheshire Basin, and are effective in reducing the average rate of dip. The 45° hade of these fractures is exceptional, and must have come by tilting as displacement continued during and after the deposition of the Permian and Trias. South of Manchester the fractures bend southwards as they tail off in the sharp rise of measures in the Cheshire margins of the Peak. Towards the north the leading fault lines take a double bend, and swing round first westwards and then northwards to cross the Rossendale anticline. In North Lancashire, and all the way from Wigan to Todmorden, the pattern is broken by the great encircling fault group into which both from north and south the local strip fractures trail. In South Lancashire to the west of the great Pendleton-Irwell Valley Fault, the north-west breaks are less powerful and more widely spaced. There are also strike faults, possibly an arcuate series, in the edges of the Cheshire Basin, and about Wigan and St. Helens a diamond block pattern, not unlike that of Yorkshire, has resulted.

The swarm of faults which in North Wales slices the country into narrow strips range generally north and south, with some eastward convexity, and cut across the horseshoe folds obliquely. Northwards

[15] P. F. Kendall and H. E. Wroot, *Geology of Yorkshire*, p. 243 (1924).

from Wrexham, and along the Dee estuary, they diverge somewhat to the westward, but east of Hawarden they bend as if to complete beneath the Trias the encircling fractures of the Cheshire Plain. The continuation of the Bala or Llanelidan Fault tears across the whole Carboniferous outcrop, as does the east-west fault through the Vale of Llangollen. North-south faults trail into or branch from these old deep-seated fractures, by whose repeated movements the wedge of ground between them may have been subjected to horizontal torsional stress. The ring of fractures round the slab of Ruabon Mountain is not matched in any British coalfield. Further to the south, longitudinal faults bend south-westwards, and the Denbighshire Coalfield ends at east-west cross-fractures which also cut the Trias.

Within the Cheshire Basin faulting is recorded only in broken outcrops of Triassic sandstones. The known pattern follows that in neighbouring outcrops of Carboniferous rocks. At the Staffordshire border the Red Rock Fault is at once marginal to the basin and longitudinal in the flank of the Rearers anticline. Across it both folding and fault movements have been renewed since the deposition of the Trias.

Between the Red Rock Fault of Cheshire and the plateau of the Peak, fractures which gather from East Lancashire die in the lower flanks of the steep upfold. Along the crest of that main Pennine fold in Yorkshire and Cheshire, longitudinal displacements replace the narrow folds converging to it from the south, and form the Pennine anticlinal fault. Out of this across the Millstone Grit moors, minor branch fractures, cross-connected, curve away to the eastward in a wide half-circle, to join the longitudinal series of the Yorkshire and Derbyshire Coalfield.

The triangle of country which lies between the Peak of Derbyshire, the Longmynd and Charnwood, has longitudinal faults which branch as they diverge southwards in the middle limbs of folds. As boundary faults in the edges of the exposed coalfields of the Midlands, some of these are associated with great change of stratigraphical level. They range with slight obliquity to the strike of pre-Carboniferous structures, and are in the flanks of late Carboniferous upfolds, which have completed perhaps the last third of their movements during or since the deposition of the Trias. Faults developing in the limb of the western anticline of Staffordshire turn and cross the Potteries syncline obliquely, their considerable throw reducing the effect of southward pitch. Numerous adjustment faults, often in pairs, traverse the crests of anticlines in the North and the South Staffordshire coalfields, and also the coalfield synclines of South Derbyshire and Leicestershire. Only east-west faults of the arcuate group in the northern margin of the Staffordshire-Trent Valley Basin are recognised as breaking across both anticlines and synclines, or as having direction unrelated to Carboniferous and older structures.

In his studies of structure in the country between the Longmynd and the Berwyns, Wedd has discussed the development of faults by resolution of horizontal stress to lateral shear or spiral torsion, where compact rocks have met obliquely an advancing Hercynian crustal wave. Possibly structural disposition along other ribs of reinforcement in the pre-

Carboniferous floor of the Midlands has located faults of lateral shift, but details await attention, and the subject is too large for further discussion here.

Coalfield Dimensions.

In the foregoing description and discussion of structural pattern, reference to size has intentionally been omitted. In coalfield engineering size is the prime factor controlling development, so, for the better application of the principles which have emerged in the qualitative analysis, I shall conclude with notes on the dimensions of those structures in and about the several coalfields of the province which have been proved, or are likely to prove, important in industrial planning and development.

The largest and most productive of British coalfields is that of Yorkshire, Derbyshire and Nottinghamshire, the East Pennine or East Midland Coalfield, a continuous complex downfold or synclinorium, more than seventy miles long between Bradford and Nottingham, and forty miles wide along the river Don. Half or more than half of its total area to and beyond the rivers Ouse and Trent is buried under Permian and Trias ; and there, though folds and fault belts from the exposed area can be projected, real knowledge of pre-Permian structure has only come with mining exploration and development. Denudation had taken toll of all the upraised anticlines before the Magnesian Limestone was deposited, and so between Leeds and Nottingham the Basal Permian rests in turn on each and every member of the Productive Coal Measures series.

The Yorkshire Coalfield north of the Don is a comparatively simple dish structure, cracked and broken by its faults. Its deepest part is the Frickley trough between Pontefract and Doncaster, where the floor of lowest Coal Measures lies 4,500 ft. deep twenty miles in from outcrop. Towards the south the broad swell of the Don anticline ends in the 1,500 ft. deep descent to the Maltby Basin, whose slope is broken *en echelon* by the north-easterly Don Faults. Between Doncaster and Worksop the central part of this South Yorkshire Basin includes a patch of Upper Coal Measures, and here, with 5,000 ft. of Productive Coal Measures, is probably the deepest part of any coalfield east of the Pennines. Despite truncation at the Permian unconformity, some Productive Coal Measures extend for several miles beyond the Trent.

Contrasting sharply with Yorkshire, where faults are the main disturbers of continuous mining development, Derbyshire is characterised by steep-sided folds of variable pitch, which undulate the measures in troughs and arches, nearly, but not quite, high enough to obscure the synclinal structure of the coalfield as a whole. From the suburbs of Sheffield, the Ridgeway-Renishaw anticline, 1,000 ft. high, pitches south-eastwards and bulges the Silkstone Coal outcrop some six miles east, and continues by Barlborough and Whitwell underneath the Dukeries. Four miles to the south, it has for neighbour the curving hogsback of the Brimington anticline, which for eight miles between Holmesfield and Duckmanton maintains an even crest level, while the syncline of Dronfield, Staveley and Bolsover, pitching with undulations, descends 2,000 ft. alongside the steep east-facing flank which at Brimington rises 1,000 ft.

within a mile. The back slope to the Chesterfield syncline starts immediately, and, though not so high, is similarly steep. By sudden change of pitch and oblique cross-faulting, 600 ft. of crest elevation is lost at Hasland, and about Heath the hogsback becomes a terrace. Southwards the crest picks up in the 500 ft. high, mile wide, cracked dome of Hardstoft, beyond which, broadening as it pitches, it flattens out eastward in the swell which holds the coals at convenient depths across the Sherwood Forest area east of Mansfield. The Chesterfield-Clay Cross-Tibshelf syncline, two to four miles wide, 500–1,000 ft. deep, broadens and opens out to the Oxton-Thurgarton Basin of Nottinghamshire. It is bordered on the west by the uneven crest which brings limestone to surface at Ashover, and by the broken dome of Ironville, three miles long and two miles wide, in which the measures rise 600 ft. This towards the south-east is paralleled by the wider anticlines of Cossal and the Erewash Valley. Further to the westward are the local basins of Swanwick, Ripley, and Heanor—this last two miles wide and 500 ft. deep—which form dimples in the terrace in which the margin of the coalfield extends south-westwards towards Derby.

Concerning the extension of fold structures beneath the Nottinghamshire Trias, more, and more exact, information is desirable. In Derbyshire no trough or crest line ever keeps an even course, and though on a small-scale map we may outline in simple curves the information available from existing pits and boring records, it is not to be expected that all pre-Permian folds in Nottinghamshire are broad and open. Levels in the Top Hard Coal between Welbeck and Ollerton rise to the eastward, and within two miles there is a further steeper rise to Wellow. Explorations along the line from Mansfield to Kirklington show sharp diversities of level of quite 1,000 ft., and to the south of this line, borings at Farnsfield, Oxton and Thurgarton have proved 500 ft. of red Upper Coal Measures infolded underneath the Permian. Despite the presence of Upper Coal Measures in this central trough of Nottinghamshire, because of southward thinning of the several subdivisions of the series, it is likely that the deepest part of the Nottinghamshire basin is shallower by at least 1,000 ft. than that of South Yorkshire.

As the East Midland Coalfield fills the broad synclinorium which flanks the Peak uplift on the east, so the Lancashire coalfields, and whatever there may be beneath the plains of Cheshire, occupy the deeper downfold which abuts upon it from the west. Extended Charnwood, being more rigid, has been given greater elevation than the prolongation of the Longmynd, but west of this latter under the great oval area which extends from Manchester to Shrewsbury (sixty miles), and from Chester to Congleton (thirty miles), Carboniferous rocks are so deeply depressed and covered with Trias as to have remained unproved. A borehole 2,500 ft. deep at Plumley near Northwich ended in Keuper, and under the central 500 ft. of Lias proved at Prees the basin is probably deeper still.

The fall-off westward from the Peak within the East Lancashire coalfield to Manchester, is amazingly steep, 7,000 ft. within the six miles of mining ground between Oldham and Manchester, 3,500 ft. in an unbroken two-mile dip-slope under Stockport town ; and the whole thickness of

the local Carboniferous from the lowest D1 to the zone of A. tenuis has been exposed and bevelled off in the sixteen miles between Miller's Dale and Stockport.

Steep dips in the Manchester corner of the Lancashire Coalfield are half compensated in the pitch of the broad Cheshire syncline by low-hading, north-westerly throw-back faults, which die in the limbs of the anticlines on the north and east. The Irwell Valley-Pendleton Fault, with a throw of not less than 2,000 ft. under the suburbs of Salford, is about the last and the greatest of the slasher system faults. Beyond it, with steepness decreasing from 1 in 3 to 1 in 6 or less, the Lancashire outcrop of Productive Measures sweeps westward to Wigan, where, across more faults, it elbows south by St. Helens and Prescot, and so beneath the Trias and across to Wales. Decrease of dip in Lancashire is associated with transgression of Productive Measures by Permian or by overlap of Trias on to Millstone Grit towards the west.

The northward rise of Coal Measures from under the Cheshire Basin continues to a height greater than their local thickness, which in the east exceeds 8,000 ft. Across the ten miles wide plateau of the Rossendale Anticline which ranges east-west from Bacup to Chorley, the beds of Millstone Grit are almost flat, and stratigraphically only some 1,000 ft. lower than in the neighbouring crest of the Pennines, from which this fold is separated by a mile-wide sloping ridge or neck.

The North Lancashire Coalfield is a triangular downfold only some 1,500 ft. deep, tucked in between the Rossendale plateau and the Pennines, and is cut off towards the north-west by the sharp uprise of Millstone Grit and Lower Carboniferous, which outcrop in the Forest of Pendle and the lowlands of Craven and the Ribble. This shallow downfold contains little more than Lower Coal Measures.

The horseshoe folds of Flintshire lie to the east and alongside the upstanding mass of limestone and Lower Palæozoic rocks of Denbigh and Snowdonia, much as the folds in Derbyshire flank the east side of the limestone massif of the Peak. The most easterly of them through Hawarden, rising and falling transversely 2,000 ft. in about three miles, is of similar dimensions to the Brimington anticline. By Caergwrle it turns into the profound pre-Trias disturbance of the Llanelidan Fault, a branch of the Bala Fault which crosses Wales. The Denbighshire part of the coalfield is also traversed by a 1,000 ft. fault through the Vale of Llangollen, but most of the curving fractures which cut the North Wales coalfield into longitudinal strips are mainly effective in stepping back steeply-inclined measures as they dip under the Trias of the Cheshire Plain. The westerly transgression of the Trias in Lancashire is matched south of Chester by the sudden incoming of the Midland type of Upper Coal Measures at the line of the Bala Fault. By Wrexham these red beds increase in thickness, and, overlapping the Productive Measures against pre-Carboniferous rocks of Shropshire, are probably continuous to Staffordshire and provide a large part of the filling of the southern half of the Cheshire Basin.

Although it adjoins the Cheshire Basin, there is no suggestion that North Staffordshire was ever downfolded with it. The utmost that can

be claimed is that the marginal strip of coalfield between the crest of the Rearers Anticline and the Red Rock Fault was dragged down as the basin deepened. The Rearers Fold or Western Anticline of Staffordshire is interpreted as an acute upfolding of an extension from the Longmynd. Within the coalfield, mining has proved that the coal seams rise and fall transversely across it 1,500 ft. within three miles, and that where the fold is asymmetrical the slight overturn is towards the west. Where, by Astbury, the convergence at the Red Rock Fault brings Trias against D2 limestone, the eastward drop into the Biddulph trough introduces 5,000 ft. of measures within two miles. The divergent Eastern or Endon anticline is a part of the gentler north-eastward rise out of the Potteries Coalfield trough towards Derbyshire, and is defined eastward by the steep-sided shallow syncline of Rudyard and the narrow flat-bottomed Shaffalong Coalfield. The main trough of Staffordshire pitches a little to the west of south at about 500 ft. per mile, but powerful north-west faults make the pitch only partially effective. In fifteen miles the coalfield widens southward from one to fifteen miles, and within its gape there is, about Newcastle and Trentham, already 5,000 ft. of Productive Measures overlain by more than 2,000 ft. of Upper Coal Measures. Within North Staffordshire, Trias transgresses and is banked against every member of the Carboniferous series, and is itself quite steeply tilted by secondary uplift of the Rearers and other anticlines.

The southward pitching of the Potteries downfold is towards Newport and the East Shropshire Coalfield. Inlying outcrops of red Upper Coal Measures follow the line of the Rearers fold towards the Longmynd, but spread also eastwards towards Lilleshall, where a sharp uprise of the Wrekin ridge brings up Cambrian and Carboniferous Limestone, and the only suggestion of closure of the Stafford-Shropshire basin includes the great oval of Trias and Upper Coal Measures which extends forty miles south to Kidderminster and Bewdley, with Stafford and Wolverhampton on its eastern side. In this downfold, as in the southern half of the Cheshire Basin, the Upper Coal Measures are thick, but development from the deep pits already working out westwards from the Black Country is evidence that almost all its deep downfolding is subsequent to the deposition of the Productive Measures.

The South Staffordshire or Black Country Coalfield is essentially a twenty mile long, four to eight miles wide, flat-topped, north-south ridge or plateau, tilted slightly towards the south and diversified with minor ridges and hollows, which are re-awakened pre-Carboniferous structures. From the trend of its minor folds and bounding faults one may guess that it lines up with the Eastern (Endon) anticline of North Staffordshire, and that the pitch which brings up limestone under Trias north of Cannock is responsible for the ending of the coalfield there.

As the Black Country is a plateau, so the Lichfield-Birmingham Trias area is a steep-sided downfold several thousands of feet deep, widening southwards and flanked towards the east by the rise to the Warwickshire Coalfield. Possibly this is the trough of the Cheadle Coalfield continued southward under the Rhætic outlier of Abbots Bromley, but a local rise of pitch allows rocks older than the Trias to appear at surface between

Walsall and Tamworth, and so divides an Uttoxeter-Burton-Lichfield basin from the Birmingham-Stratford syncline to the south.

The Warwickshire Coalfield is an open syncline two to seven miles wide, which widens as it pitches down toward the south. Between Kenilworth and Coventry it contains over 4,000 ft. of pre-Trias red beds, the thickest development of Upper Coal Measures known in Britain. It is elevated somewhat above the level of the Birmingham syncline, from which the Productive Measures are separated by the crest of Cambrian rock which outcrops at Dost Hill. Towards the east the Warwickshire Coal Measures rise sharply with the Nuneaton ridge of Cambrian and Pre-Cambrian, over and against whose east-facing side the Leicestershire Trias banks and overlaps. This spread of Trias is continuous with that of Lichfield and the Trent Valley, but whereas as far as the western margin of the Warwickshire and South Derbyshire Coalfields the Lichfield trough contains a great thickness of Red Upper Coal Measures underneath the Trias, the Cambrian and older rocks of Leicestershire form a diversified upraised platform and upon it the Bunter is overlapped by Keuper.

Across the Leicestershire platform, shallow folds of variable pitch strike in a general north-westerly direction towards Dovedale and the convergence of North Staffordshire, in parallel with the south-west edges of the Peak. On it, *en echelon* on either side of the south-east-pitching Ashby anticline, lie the coalfields of South Derbyshire and Leicestershire, each six or eight miles long and containing about 1,500 ft. of rich Productive Measures across which the Trias rests directly. The structural boundary of the Leicestershire Coalfield towards Charnwood is peculiar. For miles it is a steep fold, broken by a fault, the fissure being occupied by an igneous intrusion. But as the fault bends round north-westward it cuts across the pitch of the folds, and, whereas on the coalfield side with eastward dip older rocks appear in order northward from under the Coal Measures, on the Forest side towards the north the Pre-Cambrian is succeeded by Carboniferous Limestone; and west of Melbourne, where Millstone Grit is overlain by Trias, this powerful boundary fault has lost its throw. Movements along this fault were completed before the overstep of the Trias.

Conclusion.

In the assembly of this information I have noted many structural associations the significance of which has not been elucidated. The plotting of formational thicknesses of strata by zones has confirmed the Midland Province as a structural unit of deposition. Examination of Coal Measure stratigraphy has proved its slow development as a Coal Measure geosynclinal basin which was everted before Permian time. In cross-section the folding of the Province is duplex in all directions, and in general it is now a synclinorium with a central lop-sided crumpled dome. This bifid, asymmetric elevation, which is the central Pennine fold, divides the eastern coalfield from a western, more deeply depressed, Trias-filled syncline, and within the fork of double uplift is Staffordshire and the fingering coalfields of the Midlands.

The narrow folds which compose the western branch of the Pennines

have for core in Shropshire the worn plexus of Lower Palæozoic rocks which had been foothills to the Devonian Caledonian Alps. The Charnwood core of the eastern limb in Leicestershire is compressed Pre-Cambrian and igneous material. Several, probably all, synclines within the Carboniferous synclinoria are disposed between ribs of reinforcement in the pre-Carboniferous foundations, which are aligned with the anticlinals of their cores. The synclinals deepened intermittently but progressively as the geosynclinal filled ; and though as a whole the Province may occupy an early downfold in the foreland of the Hercynian alpine chain, its leading fold-lines are re-emphasised and rejuvenated structures which in origin are older.

In the beginnings of my study of fold and fault distribution in the Pennines, I was content to follow custom, and use established regional names for trend. The East Pennine Coalfield has obvious north-west-south-east elongation and is continuous to Charnwood. Its longitudinal folds and faults, though they bend in flowing curves, do not stray far from the Charnian direction. The north-east-south-west oval of the Cheshire Basin may be Caledonian, and though it lies athwart the compressed folds of Wales, it is flanked by folds and faults which are rejuvenated Caledonian structures. The Pennines as a hill range trend north and south, but north-south folds are only dominant in them for some twenty miles along the borders of Derbyshire and Cheshire, where they are bunched between the Caledonian trough of Cheshire and the Peakland extension of the Charnwood ridge. Continuing with slight divergence through North Staffordshire, they point southward as a hand with outstretched fingers, the thumb along the Caledonian folds of Shropshire, the long fingers following the coalfields of the Black Country and Warwickshire, and the little finger the Charnian of Leicestershire—a Midland fan of congruent folds and faults, Caledonian and Charnian, but on the average ' Pennine ' in direction. Northwards also, but in curves which are asymmetric, trend-lines from the central Pennines open out, in Lancashire bending westwards but in Yorkshire eastwards, to return southwards and unite with Charnian structures in Derbyshire and Nottinghamshire.

Surely in this continuous variation of fold and fault direction within the type area from which the Pennine trend was named, we see the application of regional trend nomenclature reduced to an absurdity. The Pennine uplift is not a simple group of parallel pressure ridges ; and, having traced the loosening of its sheaf of structures through the Midlands, and seen them almost box the compass in the coalfields on either side, I have concluded that as a synonym for north-south trend of structure the name of ' Pennine ' must disappear. Forced correlation in use of nomenclature cannot express tectonic virgation, and for precision in indicating fold direction in the course of this address, I have gone back to compass-bearing, and for specifying fault-lines I am content to mention their alignment and locality.

Charnian, Caledonian, Hercynian, are well-established names for ancient mountain ranges. With reason they are used to designate structure impressed when those mountain folds were being compressed.

During the filling of the Coal Measure geosyncline, local folds of the Pennine family were lines of delayed settlement, and it seems unlikely that the Midland Province area was then being compressed. Moreover, within this area the flanks and crests and troughs of the folds affecting Carboniferous rocks are broken by normal faults of extension, whose ' wants ' or ' barren areas ' go far to compensate the shortening of the base line required for maintenance of continuous cover for the folds. From mining records we have indications that certain longitudinal faults had cracked and suffered adjustment as the Coal Measures were deposited, but the main displacement of all coalfield faults belongs to the time of Hercynian uplift, after the accumulation of the Upper Coal Measure Red Beds, and before the planation which made ready for the deposition of the Permian.

By pattern and by distribution over all the area studied, Pennine and older and newer faults and folds are so closely associated that it is inconceivable that they should have come into existence or developed separately. Lateral compression does not explain the existence of normal faults along the middle limbs of folds, nor the characteristic back-step adjustments in the pitch of troughs ; and by stages Pennine structures must have been both tensional and compressional. Only by meticulous measurement of the extent of wants and barren areas in disrupted sheets of sediment which were once continuous, such as coal seams, could the relative importance of positive and negative strains be evaluated. It is in the hope that geologists interested in such problems will seek out and compute the exact geometrical information available in coalfield mine plans, that I have stressed their interest in the opening remarks of this address.

THE MECHANICAL VIEW OF LIFE

ADDRESS BY

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PRESIDENT OF THE SECTION.

Each year it becomes more difficult to review the progress which is being made in the diverse fields of modern zoology, for as individuals we are necessarily specialists, and we tend to forget that the greatest contribution which zoology has ever made to human thought was not the result of a specialised inquiry. The concept of organic evolution was, on the contrary, a brilliant process of integration from every branch of the subject, which spread its effect far beyond the confines of zoology itself. Although it is impracticable to review, even in the most general terms, the progress of the science as a whole, it is perhaps possible to take stock of one particular branch of the subject and to discuss its contributions towards problems which are of some general scientific and human interest. To an increasing extent, experimental zoologists are borrowing the weapons of physical chemistry, and possibly the time has come to consider the general point of view which underlies this type of attack on zoological problems. What is our conception of the essential nature of the living organism ? Do we believe that the activity of living matter and its potentiality for change can be expressed adequately in terms of physical units ? Do we incline to the belief that living animals have been evolved from inanimate matter ?

The aim of experimental biologists is to express the living organism in terms of its dynamic activities and to consider its structure as an active and functional machine. It is not infrequently suggested that this is the province of the physiologist and the biochemist. I venture to think that this is not the case. Let us consider one of the fundamental tissues of an animal's body from the point of view of the physiologist and from that of the zoologist. To the physiologist, a muscle is all but invariably an isolated preparation functioning under conditions which are often remote from those which exist in the body of the organism. Such preparations have thrown light on the phenomena of muscular contraction, and on the process whereby the muscle is induced to contract when it receives a nervous impulse. On the other hand, how many physiologists know, or are even interested to know, how a frog jumps ? To the zoologist a frog's sartorius should represent an essential part of the locomotory machine ; it must be studied *in situ* and in a way which will illuminate, not the nature of a muscular twitch, but the behaviour of the animal in its own natural habitat. It is idle to suggest that there is not much common ground between physiology and experimental zoology, but, from a broad standpoint, the conception of the organism as a single living

entity is, or should be, the more peculiar attribute of experimental zoology. To some extent it is true that we cannot understand the full potentiality of a frog's musculature until we have a precise knowledge of the dynamic properties of a muscle fibre. The fibre is, or appears to be, a less complicated system than the muscle which is working *in situ*, and it is tempting to start with the simpler unit and to pass on to the more complicated systems by a series of apparently logical steps. To a significant extent this argument has appealed to experimental zoologists. We start by being interested in the organism as a whole, but soon decide to concentrate on one specific organ. Eventually the organ gives place to the cell, and thence it is an easy step to the bottom of the ladder where we gather together to discuss the structure and the functions of living material in terms of atoms and molecules. This point of view is of peculiar significance, for, by means of a common language, zoologists, physiologists, chemists and physicists have developed, and are continuing to develop, a fruitful field of work. It is, however, a field on which it is dangerous to tread without adequate safeguards. It is all too easy to over-simplify a problem and to ignore the fundamental properties of living matter ; it is all too easy to make artificial pearls and cast them before appreciative swine. It is, nevertheless, in this field that the foundations of all biology eventually may rest, and perhaps the time has come when we should review, as impartially as we can, the relationship between the animate world of animals and the inanimate world of the physical chemist.

The application of physical and chemical methods as instruments of biological research needs no defence. Its justification is seen in the results which have been obtained. During the past twenty-five years our knowledge of the living cell, of the respiratory process, and of the mechanisms of nerve and muscle fibres has been placed on a high level of precision by methods which are identical in type with those used for the study of physico-chemical processes in inanimate systems. In so far as these results bear on their own peculiar problems, zoologists must accept them, and they must influence our conception of the organism as a whole. By using appropriate methods we can define the physical properties of living matter, but there always remains the possibility that the living organism may possess properties of another nature which cannot be defined in physical units.

When, as biologists, we are asked to define our conception of the nature or origin of living matter, we must confine ourselves to views which are based on the facts of observation. The more accurate and extensive are our observational data, the more precise and the more satisfying will be our conclusions. The material with which the biologist must deal is of extreme diversity and complexity, and we naturally turn to the physical world for standards of measurement which will help us to arrange our material and to place our observations in a reasonable relationship to each other. As I understand it, the age-long discussion between the mechanistic and vitalist schools of thought turns on how far we believe—on the basis of observation—that the facts of biology can be sorted out into an harmonious and satisfying series without invoking conceptions which are found to be unnecessary in dealing with the facts of observation within the physical world. The centre of gravity of the problem shifts from

time to time, but for many years two concepts appear to have influenced the discussion to a marked extent. Firstly, the synthesis of organic compounds from inorganic material suggests that there is no fundamental difference between the type of substances found in or made by living organisms and those which are found in or formed by purely inorganic systems. Secondly, the inferences drawn from the theories of organic and terrestrial evolution suggest that these two processes are fundamentally similar and involve the operation of fundamentally comparable forces. Not a few biologists have in fact maintained that living matter 'owes its origin to causes similar in character to those which have been instrumental in producing all other forms of matter in the Universe' (Schäfer, 1911). This was the view of Ray Lankester, who elaborated a series of intermediate steps whereby the first type of living organism was evolved from inanimate matter. I imagine that not a few modern zoologists would tolerate, if not actually accept, a similar view. From this it is often, but not always, implied that there is a fundamental continuity in the properties of all matter and that the only properties which a living organism can possess are those which can be defined in physico-chemical terms.

Opposition to such a view has not been wanting. In 1912 Sir Oliver Lodge replied to the views set forth by Sir Edward Schäfer and stressed the existence in organisms of a principle, not easy to define, which is absent from the world of physics and chemistry. From time to time the battle has been renewed, and both biologists and physicists have taken an active part. It is a curious but pertinent fact that the most far-reaching mechanistic views have been and are being put forward by biologists, the more cautious views or the vitalistic views are held by physicists and chemists. T. H. Morgan, the author of so much fundamental work in the realm of pure biology, states in a recent book: 'When, if ever, the whole story can be told, the problem of adaptation of the organism to its environment, and the co-ordination of its parts, may appear to be a self-contained progressive elaboration of chemical compounds.' Even Dr. Barnes accepts the spontaneous origin of living matter as a natural phenomenon: 'If we could reproduce in the laboratory the conditions which existed upon the earth when life first appeared we should cause it to appear again.' On the other side, we find physiologists (whose experimental contributions to science are of a severely physico-chemical nature)—J. S. Haldane and A. V. Hill—regarding the purely physical outlook with distrust. It all seems rather like Alice in *Through the Looking-glass*.

The exponents of the mechanistic view have been curiously indefinite in the exposition of their opinions. I confess that a study of the more popular works on physical science leads me no nearer to an understanding of those 'causes' which, according to Sir E. Schäfer, 'have been instrumental in producing all other forms of matter in the Universe'; nor have such chemists as I have had the good fortune to meet been very familiar with the concept of 'co-ordinated series of self-regulating and self-propagating chemical reactions,' such as are described by Prof. Hogben. According to Prof. Hogben, we may look for a complete solution to the nature of life within a mechanistic framework, fortified by the conviction that 'The mechanist has a cheerful attitude to knowledge

and refuses to capitulate to the fear of the Unknown: the vitalist, a sadder but not necessarily a wiser type, finds balm in the limitations and failures of human effort.' So far as I have been able to observe, it is by no means obvious to note in the writings of Dr. Haldane, Prof. Hill, or the Bishop of Birmingham those signs which are usually associated with a contemplation of the failures of the human intellect.

The mechanistic view of life seems to imply that if, at any instant of time, we were to know the precise distribution of the matter and energy which are present in an organism, we would have a complete understanding of all its properties. In other words, the behaviour of living systems can be completely defined in terms of laws which are fundamentally similar to those which describe the behaviour of inanimate systems. It is of interest to consider how far this conception is based on the results of observation, and how far it rests on a rather indefinite foundation of intuitive belief.

Let us look for a moment at the theory of the evolution of animate from inanimate matter. From a biological point of view it seems at first sight reasonable—it seems to be the natural conclusion to draw from the process of evolution which characterises the world of living organisms and the universe as a whole. The theory gives us a comfortable feeling of continuity of thought. Let us look at the position from a physical point of view. As a physical phenomenon it is undoubtedly *possible* for a living organism to have been evolved spontaneously from inanimate matter. It is also possible for a stone to leap spontaneously from the surface of the earth. These things are possible, but are they probable? To obtain some estimate of the degree of probability it may be useful to consider the phenomena of Brownian movement. As biologists we are very familiar with the spontaneous motion of very small particles lying in a liquid medium. We believe that each excursion is due to a difference in the intensity of molecular bombardment along the axis of movement. The smaller the particle, the greater is the chance that a molecule of water will hit the particle without a simultaneous encounter from another water molecule coming in an opposite direction. Water molecules are moving at random, and the direction of collision is one of chance—the larger the particle, the greater is the chance of an equal average intensity of bombardment from all directions at any given moment. Now since all water molecules are free to move in any direction, the actual number of molecules moving in a common direction at any given moment will vary from moment to moment, and the same is true for the molecules of a pebble on the ground. It is *possible* for all the particles in a suspension of Indian ink to move simultaneously in one direction. It is also possible for all the molecules of a pebble to perform the same feat—but in view of the very large number of other possibilities, the *probability* of simultaneous co-ordinated movement is very, very small unless we are dealing with very small numbers of molecules. The degree of smallness can be judged by putting ten black and ten white balls into a box and drawing them out at random in lots of ten. The probability that we will draw ten white or ten black balls is five times in one million. If we increase the numbers and draw one hundred balls, the probability of drawing balls all of one colour is so small that we say that anybody who

expected it to occur must be slightly demented. In the case of the Brownian particles, the chances of ten contiguous particles moving simultaneously in the same direction are even smaller, and in practice we sum all this up by saying that as long as we are dealing with reasonably large numbers of molecules, the events which we observe are the most probable events, and we assume that the improbable events do not in fact occur. On this arbitrary but effective basis rest most, if not all, the laws of physics and chemistry which we apply to the study of living matter. We say, in effect, that stones do not leap spontaneously from the earth because the chances against it are so extremely great ; similarly we state that the pressure of a gas is always inversely proportional to its volume, except on a negligible number of occasions. The organisation of the simplest living organism is clearly more complex than that of a stone or of a motor car, and it carries out processes which are infinitely more complex than the sorting out of black from white particles. What, in fact, is the probability that any chance distribution of molecules should lead spontaneously to the dynamically active mechanism of the living organism ? Would any serious credence be given to the suggestion that a motor car or even a footprint on the sands came spontaneously into existence without the intervention of directive forces ? Why, then, should we accept the spontaneous origin of living matter ? It is possible, but it is so improbable that, if considered as an observable phenomenon, in any other sphere of human thought it would be discarded as a figment of a deranged brain. Why should biology accept a standard of probabilities incomparably less satisfying than that of other branches of knowledge ?

Left to himself, the chemist does not seriously consider the *spontaneous* origin of proteins from CO_2, water, and simple salts, nor does the physicist admit the spontaneous origin of organised machines. Biology itself provides not one shred of observational evidence to support the spontaneous origin of living matter in the world to-day, and yet not a few biologists are prepared to postulate the spontaneous origin of intermediate stages between the living and the inanimate worlds—to my mind, the spontaneous origins of these stages represent physical events which are so improbable that we cannot describe them in terms of ' laws ' which only apply to events of an entirely different order of probability : if these intermediate stages actually occurred they must be classified as miracles, not as ' natural ' events. We may be told that in past ages, events which are now very improbable were in fact of quite frequent occurrence. As scientists we cannot accept this statement without some assurance as to what were the nature of the conditions which made the origin of life inevitable or even probable. The distribution of energy and of matter in past epochs may have been different ; but if such conditions produced the living organism, is it not strange that every attempt to reproduce them in the laboratory have completely failed ?

We can put the facts in another way. Within the physical world all systems appear to move towards the state of greatest probability, and the events which take place within a dynamic system are those which tend to destroy structure and not those which elaborate it. Is there any evidence which suggests that, within the physical world, a dynamic machine has spontaneously come into existence ? That such an event might

happen is true, but has it, in point of fact, ever occurred under the observation of mankind ? Unless a positive answer can be given to this question, the belief in the spontaneous origin of living matter seems to be a negation of the principles which underlie scientific thought.

If we decline to accept the spontaneous origin of living from non-living matter, there is no particular reason why we should hope to express all the properties of an organism in terms of physical laws ; we might just as reasonably try to express physical phenomena in terms of biological conceptions. It seems more logical to accept the existence of matter in two states (the animate and the inanimate) as an initial assumption. Some properties are naturally common to matter in either state, and it is therefore legitimate to study the so-called physical properties of living matter ; but just as the fundamental concepts of physics are based on observational facts, so those of biology must conform to the same conditions. The physicist is not concerned with the origin of inanimate matter ; he is content to investigate it as he finds it. The biologist must likewise accept the living state as he finds it and not allow his science to rest on theories, however spectacular or attractive. It is not easy to define Life, but in practice most people will admit that matter in the living state possesses characteristics which are fundamentally different from those of inanimate objects.

The central characteristic of living matter is its state of organised dynamic structure. This is obvious in all the larger forms of animal life, but it is equally true in so-called ' homogeneous ' protoplasm. This important fact emerges from the study of such cells as the eggs of echinoderms and molluscs. From a biological point of view, the eggs represent not only very remarkable chemical laboratories, but also systems which are capable of transforming themselves spontaneously into highly differentiated organisms. A study of the physical properties of the eggs shows, conclusively I think, that the cytoplasm consists of a fluid matrix in which lie the granules which are visible under the microscope. The viscosity of the fluid matrix has been measured by observing the rate at which granules or particles move through the cytoplasmic matrix when exposed to a given intensity of centrifugal force—and the value so obtained is confirmed by observing the velocity at which such granules redistribute themselves spontaneously by Brownian movement. We conclude from such observations that the cytoplasm of the cell with all its complicated biological properties possesses, in the aggregate, the general properties of a liquid and not of a solid. Similarly, the immature nucleus of the oöcyte has the general properties of a fluid, and yet it proceeds spontaneously to form the highly differentiated system seen during meiosis. Within the fluid system of the cytoplasm or the nucleus, single molecules or aggregates of molecules will distribute themselves at random (just as do the granules we can see through the microscope), unless these molecules are subjected to suitable restraint. When we try to picture the cell or the nucleus as a complex chemical laboratory, it is by no means easy to visualise the type of forces which are necessary to hold the various particles or molecules in their proper position relative to each other. Were the matrix of the cell of a solid nature, the problem would be much simpler. It may be suggested that the application of centrifugal force destroys the real struc-

ture of the egg, so that under natural conditions the cytoplasm possesses the properties of a solid rather than those of a liquid. If this be the case, we are faced with the striking fact that the centrifuged egg develops normally, so that any structure which is destroyed by centrifugal force is very rapidly regenerated spontaneously when the force ceases to be applied—such powers of spontaneous regeneration are unknown in the physical world. The evidence is, however, against the view that the low viscosity of cytoplasm is more apparent than real, and the suggestion is entirely inadmissible in respect to the nucleus for, in this case, the fluid nature is revealed without the application of any force other than gravity. If we base our conception of the structure of protoplasm on the facts revealed by physical methods, we must imagine a system of very great chemical complexity and of very great potentiality for spontaneous self-differentiation within a fluid framework. Protoplasm cannot be regarded as a fluid crystal, for it possesses dynamic properties which are constantly expressing themselves in a variety of ways. Two general conclusions seem possible. We may assume that the molecules of protein and of other substances in the cell are so arranged in respect to each other that they constitute a highly active chemical system, and that the mechanism which maintains this molecular orientation is such that individual molecules or groups of molecules are able to move in the way necessary to give fluid properties to the whole system but not free to distribute themselves at random. If this be the case, the whole cell must be regarded as a fundamental unit, whose organisation is such that its structure cannot be destroyed by centrifugal force. So far such an organisation is not known in dynamically comparable systems of an inanimate nature—we must regard it for the time being as an attribute peculiar to the living state, and as an attribute which is as fundamental as any of those employed for the description of inanimate matter. An alternative view is, however, possible.

We may look on a mass of protoplasm as a very fine emulsion, the fundamental units of which are extremely small. If we assume that the properties of the system as a whole are essentially those of each individual unit, then we have no great difficulty in seeing how mass disturbances fail to affect the properties of the whole system. The displacement of the particles by diffusion, or other causes, throughout the mass of the system will not influence the fundamental properties of the cell or nucleus if these properties are essentially those of the small individual units. The conception of the living cell as an aggregation of a very large number of fundamental units is in keeping with the fact that small fragments of egg-cells retain some at least of the properties of the whole system. It is also in keeping with the very small dimensions (as in viruses) within which living phenomena have been observed. There is some evidence to support the view that single differentiated cells also represent aggregates of very small living units. For example, a suspension of the spermatozoa of the sea-urchin *Echinus* in sea-water, after a period of maximal activity, enters a phase of declining mechanical and respiratory activity. If we consider a single spermatozoon during this period of senescence, we find that the intensity of its mechanical and respiratory activity declines in a way which is characteristic of a population of units which differ from each other in

their viability—the single cell behaves, in fact, as though it represented a large population of much smaller units of activity.

If we accept the view that the fundamental unit of life is extremely small, we can see that mechanical disturbances throughout a suspension of such units may induce no very far-reaching results. The conception of protoplasm as an emulsion of small vital units suspended in a fluid system is perhaps the most satisfactory picture we can derive from available facts ; but it breaks down when we try to think of the mechanism whereby the cell differentiates itself as a whole—for here we must postulate some form of co-ordinated relationship between individual units. If, however, we shelve this difficulty for the moment and accept the general conception that ' vital ' properties are associated with very small units of structure, a variable number of which are normally aggregated together as a suspension to form a single cell—it is obvious that we must exercise very great caution in the application of the statistical laws of physics in describing the properties of the fundamental units of life. The only legitimate laws are those applicable to the behaviour of single units of activity. So far as I can form an opinion, such determinate laws have not yet been forthcoming. I am inclined to think that the intrinsic properties of living matter are as mysterious and as fundamental as the intrinsic properties of the molecule of a radio-active substance : when the physicist can tell us why one particular molecule explodes and why another goes on existing, I venture to think that we can begin to consider the possibility of defining the fundamental properties of living protoplasm in physical terms. At present, however, the physicist seems more inclined to define physical phenomena in terms of biological conceptions, for, according to M. Poincaré and others, ' modern physics is presenting us with apparent examples of spontaneity and foresight.' For the moment, however, we must conclude that although physical methods have provided important facts concerning the state of living material, they have not as yet thrown much light on its fundamental properties.

If we now turn to the behaviour of an echinoderm egg-cell after fertilisation, it is again possible to define certain physical characteristics. We can observe changes in the mechanical properties of localised regions of the cell and of the nucleus, but we have no adequate picture of how these events are initiated. We are, however, acutely conscious of the high regulative power of the whole system. If we destroy, by mechanical or other means, the astral radiations seen in the cell at the anaphase of mitosis, these structures are regenerated in what we can reasonably call the right place at the right time. The whole process of nuclear and cell division, when regarded impartially as a physical event, represents an orderly process of formation of structural elements—and has physical attributes similar to those which characterise the formation of an inanimate machine from unorganised material. All attempts to define the mechanism whereby this orderly process of segregation is initiated, in terms of physical units, are, in my opinion, fanciful. It is more reasonable, at present, to regard such powers of effecting an orderly distribution of material as an intrinsic and fundamental property of living matter. The operation of this power no more involves disobedience of physical or chemical laws than does the manufacture of a motor car.

After cell division has been in progress for a very short period the cells which are formed by an egg of a sea-urchin begin to show a marked difference in arrangement from those of a polychæt worm. At the end of the third cleavage cycle, the cleavage pattern of a sea-urchin is seen to be orthoradial—the cleavage furrows between the upper quartet of cells lie immediately over the furrows of the lower quartet. In the polychæt, however, the arrangement is spiral, not orthoradial, for the furrows of the first quartet of smaller cells lie between the furrows of the basal quadrant cells. By experimental means we can force the sea-urchin egg to divide in a way characteristic of the worm. This is done by increasing the centripetal force which tends to press one cell against another, and we can show that the arrangement in the polychæt worm is that assumed by a system of spheres so arranged as to pack together within a minimum volume. The arrangement in the polychæt is essentially the same as in the egg of the mollusc or polyclad turbellarian. What conclusions can we draw ? The classical interpretation associates the similarity in the cleavage pattern with a common phylogenetic relationship. From an experimental point of view one is inclined to a totally different view—viz. that the similarity in form is due to a similarity in the intensity of the mechanical forces operating on the cells. In the worm, mollusc, or turbellarian the centripetal pressure acting on the cells is sufficient to force the cells to occupy a form in which a maximum volume is enclosed by a minimum area of surface. In the sea-urchin this is not the case. The pattern as such plays no essential rôle in determining the fate of the egg. A spirally cleaving sea-urchin egg develops normally ; it does not develop into a worm or mollusc. The mechanical view is peculiarly attractive, but it has one serious objection. When the dividing cells of a molluscan egg rotate so as to reduce their centripetal pressure to a minimum, a rotation to the left is as effective as a rotation to the right—and on each occasion one would expect an equal number of rotations to the left as to the right. In a few cases this seems to occur, but in others the left-handed or right-handed pattern appears to be due to determinate and not to chance forces—for at any given stage of cleavage all the eggs show a rotation to the right or to the left. That this phenomenon is correlated with mechanical asymmetry is quite probable, and it may be that the nature of this asymmetry will eventually be observed. In the meantime, however, we seem to be faced with the fact that a mechanical condition which is satisfiable in either one of two ways, is, in fact, only effected in one way. Does it not look as though a disturbance has occurred in the probability values of the system ? It is as though we were presented with a bag of black and white balls—and each time we pick out the black balls and reject the whites. Before we attribute a determinate behaviour to the cleaving egg-cell we must, of course, make certain that the chance of left- or right-handed cleavage is mechanically of equal probability. Up to the present we can only say that no mechanical difference is apparent—and in the absence of such definite evidence we are free to interpret the facts either as evidence of a deficiency in our knowledge of the mechanics of the system, or to the possibility that there exists in the egg a potentiality which makes certain events more probable than they could be in inanimate systems. One is tempted to suggest that the cells of a molluscan egg turn one way

or another for intrinsic reasons : an event starts inside the cells—quite independent of any external influence—just as in the exploding molecule of a radio-active substance. In other words, the cell has an individuality of its own—which is free from the limitations of statistical laws. The field of cell cleavage is full of possibilities for future inquiry, and would well repay more intensive study.

We must, however, now turn to certain wider aspects of experimental embryology, which are best observed in the eggs of the lower vertebrates. Within this field the progress of the past twenty-five years has been spectacular. By grafting fragments of the developing embryo of the newt into positions which they do not normally occupy, it is possible to get a picture of embryological development which is incomparably more satisfying than any hitherto available. We know that there exists in the egg a region or regions which are capable of influencing the fate of the neighbouring tissues. Each of these so-called ' organising centres ' determines in some way the process of tissue differentiation : the raw material is, as it were, full of potentialities for differentiation, but the exact line which will be followed is affected by the organisers. Once the process of differentiation has reached a critical stage, the fate of the tissue is determined ; before that period, the raw tissue can be built up into a variety of different structures. Quite recently it has been shown that such organisers are curiously non-specific—an organising centre from a chick can induce organ-formation in the undifferentiated tissue of a mammal ; and, still more remarkable, the organising centre does not appear to lose its activity after death. These facts are admittedly bewildering—but two points seem to emerge quite clearly. Firstly, the potentiality of the organism to control its fate is established at a very early stage. If we carry back the facts of experimental embryology to their beginning, we see that the essential biological difference between the egg of the sea-urchin and the egg of the mollusc (*Dentalium*) is a difference in the relative time at which development becomes independent of organising centres—in the sea-urchin it is relatively late ; in *Dentalium* it occurs before the egg begins to cleave. By accepting the concept of an organising centre the facts of embryology thus appear to arrange themselves in an orderly manner—and this, after all, is the supreme test of any scientific hypothesis. The second great inference to be drawn from these facts is the present inadequacy of expressing the facts in physico-chemical terms. The only point at which the phenomena seem to be susceptible to physical analysis is the apparent activity of an organising centre after death. This would suggest that the action of an organiser is either mechanical in its nature or is comparable to that of a trigger which releases specific lines of development from unorganised tissues of high potentiality. By physical methods we can hope to elucidate the physical attributes of this trigger action, but I do not think that the facts, so far as they are known at present, present a very convincing argument in favour of a mechanistic hypothesis. From a broad standpoint, the obvious conclusion we must draw from the facts of experimental embryology and from the regeneration of lost parts is that the organism behaves as a co-ordinated system even in the very earliest stages of its development ; and that this co-ordination is of a degree of complexity

quite unknown in the physical world. It is important to notice that this complexity of structure is essentially of a dynamic nature. We may say, if we feel disposed, that it is a system which is physically unstable—but where in the chemical world do we find such unstable systems acting in such a way as to build up and not to break down a highly complex structure?

It must be noted that the organising centres of the egg possess physical properties by virtue of which their activity may be influenced by external conditions. The development of a frog's egg is affected in a definite way by a gradient of temperature applied along particular axes, and we know that the egg will not develop in the absence of atmospheric oxygen. Can we not say with equal truth that the production of a motor car would also be affected by keeping one end of the factory at 30° C. and the other at 0° C.? Would it not also be affected by depriving the system of atmospheric oxygen? The effect of such conditions can be measured in terms of physical chemistry, but do they throw any real light on the type of organisation necessary for the production of a car or of an organism?

Within the sphere of embryology we can recognise, more clearly than in any other biological science, the two main attributes of living matter: (1) an inherent complexity of structure, and (2) a dynamic potentiality of initiating events which either do not occur at all or only occur very infrequently in inanimate systems.

Similar inferences can be drawn from another great sphere of experimental inquiry—namely, a study of the relationship between the fully grown organism and its physical and chemical environment, but in this case we tend to concentrate on the physical events rather than on the potentiality of the organism to control or vary its own activities. For example, many animals have the power to elaborate a peculiarly beautiful chemical machine for the conveyance of oxygen to the tissues. In such cases our main objective is a description of the physico-chemical properties of such respiratory systems, and as these are clearly susceptible to statistical treatment they can be described in terms of known physical laws. So also, in the adult animal, the phenomena of co-ordinated behaviour are clearly associated with the central nervous system, and the physical signs of this co-ordination are rapidly being analysed by appropriate physical methods, but it is important to remember that the phenomena of regulative control are present long before the central nervous system has been fully differentiated, and are not infrequently detectible in the undivided egg. If we are fully to understand the mechanisms of respiration and of co-ordinated behaviour we must bear in mind the manner in which the fully formed systems come into existence, and not concentrate exclusively on the more obvious physical characteristics of the fully developed mechanisms.

Let us now try to summarise the position. The only laws which physics has provided for an analysis of biological phenomena rest on a statistical basis; they only apply to systems which contain a large number of participating units and only describe natural phenomena in terms of probability and not of absolute truth. If we accept these laws as a means of describing the behaviour or the structure of an organism, we must

accept the conventions attached to the laws and agree to ignore such events as are improbable although they may conceivably occur. From this point of view, the spontaneous origin of living from inanimate matter must be regarded as a highly improbable event, and as such can be assumed not to have occurred. Similarly, the development of an organism from so-called undifferentiated protoplasm involves processes which are entirely without parallel in inanimate nature. So long as this state of our knowledge persists, it is dangerous to assume that the statistical laws of physics can satisfactorily describe all biological events. Our knowledge of the physical and biological properties of living matter suggests that the fundamental unit of structure is extremely small, and that it contains potentialities for change which are unique in the universe. These properties we must accept as fundamental axioms of our science which may or may not prove (in the future) to have their parallel in the physical world. It may seem presumptuous for the biologist to set up postulates peculiar to his own sphere; it would be more fitting perhaps for him to accept, with medieval humility, the assumptions of his physical brethren. One wonders, however, at times whether the concepts of intrinsic organisation and of emergent evolution are entirely absent from modern physics. Even if this is not the case, we can fortify ourselves by the knowledge that physics has from time to time changed its fundamental assumptions with advantage to itself and to the world. Those biologists who are inclined to accept the views I have ventured to put forward may be encouraged by the remark of Prof. Niels Bohr which very recently came to my notice. He says: 'The existence of life must be considered as an elementary fact that cannot be explained, but must be taken as a starting-point in biology, in a similar way as the quantum of action, which appears as an irrational element from the point of view of classical mechanical physics, taken together with the existence of the elementary particles, forms the foundation of atomic physics.'

Not infrequently the physiologist can restrict his interest to the physical properties of isolated organs—the origin of which does not concern him. The zoologist, on the other hand, knows that the beautifully adapted mechanism known as an 'organ' was evolved from a system unlike itself and may, in turn, initiate something new. For this reason, he cannot afford to forget what may be called the 'intrinsic potentiality of the living organism.' He may or may not be able to use this conception as a guide to more adequate observations, but it should be constantly in his mind. Experimental zoology can be divided into two types of study: (1) the investigation of the physical and the chemical properties of living organisms; (2) a study of the intrinsic potentialities of living matter, revealing as it does a co-ordination of events which is without inanimate parallel. In the first type of work we must use each new weapon which the physicist can give us. In the second type of work, however, biology must be the mistress and not the servant of physics or of chemistry —she must make her own foundations, and build on them fearlessly, prepared to change her views, if need be, but not prepared to force the wine of life into bottles which were designed for use in the simpler and less intoxicating fields of chemical science.

SECTION E.—GEOGRAPHY.

GEOGRAPHY AS MENTAL EQUIPMENT

ADDRESS BY

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Most of us believe that every branch of human knowledge wisely pursued—every true science, in fact—provides training for the intellect, furniture for the mind, and solace for the spirit. That this claim can justly be made on behalf of geography is the argument of an amateur observer in the present paper. To hear geography described as a science at all comes not without an element of surprise to many in our older generation, whose education followed normal lines in the third or the early fourth quarter of last century. To them geography was the dreariest part of their school curriculum, an arid catalogue of physical features and figures. To-day it presents itself as a systematic grouping of facts, with their causes and their effects, fascinating in their variety and vividly human in their interest. In this sense it is a new science, so new that many of its devotees mournfully speak of it as the Cinderella of sciences. It is, says Dr. H. R. Mills, a synthetic science—and most synthetic products are relatively new—deriving its data largely from geology, meteorology, anthropology, and other bordering sciences. Its youth, however, is among its charms ; and for its entry into the fraternity of sciences it has two illustrious sponsors. One is the gallant succession of explorers of the earth's surface, whose enterprise, though it never ceases, has reached a definite stage of accomplishment with the opening up of Arabia, the surveys of the Antarctic continent, and the flight over Everest. The other is the growing body of students engaged on the human aspects of geography, in tracing out the relations between man and his physical environment, which constitute its philosophic basis.

Being anxious to avoid all shadow of controversy, I must here pause to register the claim, pressed by Professor Burrows among others, that geography is not young but very old, as old at least as Ptolemy, a mother science which has given birth to astronomy, botany, archæology, as well as the other specialised sciences already mentioned. Which of these two views is the more orthodox may be left for another day. What is common to them both is that geography is a function of a number of other sciences ; and one of the difficulties attending its future may quite possibly be that of establishing boundaries between it and them, whether

they be lineal descendents or merely neighbours. Even the layman knows how puzzling it is—and often how unnecessary—to mark out frontiers between adjoining sciences. There will often, probably always, be an undefined borderland, into which both neighbours stray on their legitimate rounds, though working generally, unlike trespassers across political frontiers, in mutual helpfulness when they meet. Such a borderland must of necessity surround geography ; and in some directions indeed it seems to be more extensive than the science, when thoroughly established, will require. All that need be postulated at present is that, in order to be a competent geographer, it is not imperative that you should first be a skilled astronomer, geologist, and historian. Your value as a teacher and as a student will be enhanced by some acquaintance with these and the other bordering sciences ; but to the ordinary man or woman with no such equipment, geography will still offer a vast and self-contained field of intelligent interest. It is from the standpoint of this ordinary man or woman that I would invite you to survey with me some portions of the field, to consider how they serve the purposes of a true science, and then to enquire how this science can be advanced (the word is taken from the British Association's title) so as to enter more intimately into the cultural outfit of future ordinary men and women like ourselves.

I.

To many there is a particular attraction in that remote corner of the field where geography stands disclosed as a science, not of immutable but of ever-changing data, as a study not of a solid earth and everlasting hills, but of a surface amply responding to Lucretius' doctrine of flux. We mortals of the day live, it is surmised, in an inter-glacial epoch. It is only a fraction of time since this green and pleasant land of England was buried deep under an ice-cap, such as Admiral Byrd saw with something akin to terror, when he was flying in the Antarctic. It may be only another fraction of time before all that we see around us to-day is crushed into oblivion by another glacial visitation. How many such changes and catastrophes in the past will the record of geography unfold when we are able to read it ? Meanwhile we can only guess at some of them ; picture after picture of an earlier world-surface passing through the mind, without any pretence at chronological sequence. We can travel, for example, from the ice-bound Britain of which we have just been thinking to the African Sahara, then a moist, warm expanse of open grass-land, abounding in flocks and herds, and peopled by men primitive enough, but yet with a startling artistic skill in rock drawings. Or, instead of wandering south from the glaciers of Central Europe, we can turn east to the other gigantic ice-fields, which then lay over the uplands of Asia and segregated, in their own home territories, to develop on their own separate lines, the progenitors of some of the chief racial families of mankind to-day. On our way we should pass that ancient central Asian ocean which is now representated by shrunken fragments in Lake Aral and the Caspian Sea. If, following the same line of thought, we try to cast our mind still further back, we get into a sphere of endless

speculation in picturing some of the tremendous changes which have taken place in the distribution of land and sea since the Tertiary era. The union of England and France by a river valley instead of a stormy Channel would be a relatively modern feature in the landscape ; so would the land-bridges across the Mediterranean, of which only the broken piers remain in Malta and certain other islands. Working backwards, the student would see North America severed from South America by an ocean which has long receded ; and Africa divided in two by another great stretch of water. As if in compensation, he would find the Asiatic continent running unbroken through Malaya into Borneo and Java, until it faced, across a comparatively narrow waterway, the ancient Australiasian continent, which embraced Celebes, New Guinea, their adjacent archipelago and our modern Australia. To depict in the imagination a world so constituted, is given to few of us ; but I would suggest one help, however inadequate, in carrying the fancy back into the Tertiary age. Climb the Puy de Dôme—now an easy enough task—on a clear day, and let the eye travel slowly over the mass of clear-cut volcanic cones which surround you on almost every side, ranging from mountains 4,000 feet high to mere pimples on cultivated fields. Then imagine all these at work, belching out flame and fume, lava and sulphur, the sky darkened by smoke and dust, and the earth a maze of roaring furnaces. It is from such an inferno that time has evolved the smiling landscape of Auvergne to-day.

Out of any attempted survey of this particular part of the field, or what we might call pre-historic geography, two reflections emerge. The first is that, at this phase, geography is entirely dependent on other sciences, especially geology, and cannot yet claim an independent existence. The second is that, at this phase, it has hardly any conceivable interest for us except in relation to the movements of life—and primarily of man—about the globe. Amid these forgotten seas, those wastes of glaciers and zones of volcanic fire, there seem to have been stray enclaves of habitable land. It is those oases which form the focus of our interest to-day, with the help which they give in explaining the sharply differential characteristics of certain races of the human family. Or, if the mind turns rather to the puzzling similarities which have been detected in widely scattered races, it may find, in the hypothesis of old land-bridges over otherwise pathless oceans, support for the theory of early migrations. Did the primitive Mongol, after long isolation in eastern Asia, succeed in drafting some of his tribes across the Bering Strait to become the progenitors of the American Indian ? Did the human family which we call the Alpine race, imprisoned through a long glacial epoch in Turkestan, ultimately force their way into Russia, the Balkans, Mesopotamia and Southern India ? Similarly, did the stock which scientists try to disentangle as the Nordic, after protracted incubation behind the Ural mountains, issue through the melting ice into the Baltic coasts and finally dominate the Indo-European situation ? Or was the conformation of the ancient continents such as to permit the aboriginal negroes of Africa to wander, almost all the way dry-shod, the enormous distances through Asia to Australia or into Melanesia ? These are gigantic assumptions ;

but, as we know, they are not regarded as impossible by the school of anthropologists, who trace all mankind to one ancestral home. There is, of course, another theory, but the controversy is not within the ambit of my topic to-day. It may be that the march of our science will yet test both hypotheses more thoroughly than is feasible at the present state of our knowledge. There is at any rate little question that in the subject of these rival views lies the chief interest of modern man in pre-historic geography.

II.

That constant change is the law of geography, as of life, is an axiom which calls for no dramatic flights of fancy into a remote past. Change is all around us to-day; and to many lay students of geography the visible and superficial changes, as opposed to the vaster geological movements, in the face of nature have a peculiar attraction of their own. Picturesque details are always with us. One of us, for example, may have examined the treasures collected by Sir Aurel Stein as evidence that vast tracts in Central Asia, which are now no better than sandy deserts were, not so very long ago, the home of a rich and cultured people. Another may have served in Mesopotamia, and seen how the traditional Garden of Eden has been transformed into a malarial waste of marshes. A third, staying at home and spending a summer holiday on the South coast of our own country, may have reflected that Roman galleys once sailed from the beach where he stood across to the Thames through waterways which are now the cornfields and hop-gardens of Kent. These half-obliterated watercourses are for ever catching the observant eye: they abound across the railway line from Amiens to Boulogne, and their well-worn pebbles are turned up by the plough in countless English denes and combes.

The agencies of change, however, are tireless rather than picturesque; and their very assiduity makes them the fitting subject of study and experiment. Probably the easiest of them all, from the ordinary student's point of view, is the wastage of mountain ranges. Look, for example, at a hill such as the Salève outside Geneva, and no trained eye is needed to see how it is steadily slipping into the plain below. A vivid picture rises to my memory from another continent. It was one morning, after two days of torrential rain, at a hill station in the outer Himalayas. A small plateau, on which rested a military cemetery amidst a glade of deodars and rhododendron trees, had broken away during the night from the rock behind and dropped, as a solid mass, into the valley 1,000 feet below. There it lay, with the trees and the tombstones still standing, athwart the stream which ran through the valley and which was rapidly banking up into a temporary miniature lake. Some houses in the valley had been engulfed in the landslide, and several lives lost. By this time no doubt the scar on the hillside has healed, and part of the debris—disintegrated deodars, graves and ruined homesteads—is helping to build up a patch of new rice land somewhere in the Sunderbuns. The incident opened my eyes to the evidence everywhere of similar attrition which has been going on unremittingly since the mountains came into being; and

in India, with its fine cadastral records, there are potentialities of measuring the erosion of the hillsides and the corresponding formation of deltas. In most maritime countries another possibility of quantitative study exists in the relentless crumpling of the earth's surface which is slowly raising some coast lines and depressing others. These, after all, are only casual examples of the knowledge which is capable of being gleaned in this part of the geographical field—the part commonly described as physical geography. And, incidentally, it seems less than justice to stigmatise this branch of our science as synthetic. It relies for help on research in climatology, meteorology, oceanography and so on ; but its problems have a dignity of their own, and a clear place in the general pursuit of physical knowledge. The surface of our lithosphere ; its response to the influences which beat upon it—rain, winds, tides, ocean currents, etc. ; the processes of denudation, accretion, desiccation, fertility, and so on, these offer material for study and the systematic assemblage and analysis of facts which justify the claim I set out to urge on behalf of geography as a whole. The philosophy and purpose of physical geography will be discussed later ; they are in close accord with the reflections in which we indulged as we meditated on pre-historic geography.

III.

Meanwhile let me turn to another aspect of geography, more familiar to most of us laymen because it bulked so largely in our early education—that side of it which is associated with history and is sometimes called political geography. In the dark ages of last century to which I am always alluding, it hardly merited so imposing a name ; for the theme of our ordinary school maps was mainly the division of the land into national and administrative areas ; and the acme of absurdity was reached when we were set to draw maps of England, with its counties a mosiac of gaudy colours, but often with no place for rivers, mountains or even towns. From that imbecility it seems a long journey to a modern historical atlas, such for example as the admirable compendium edited by Mr. Ramsay Muir. But the relation of geography to history is still far from sufficiently intimate in our ordinary teaching of either subject. This would be true even if it referred only to the intelligent use of maps as adjuncts, so to say, of visual instruction in history. To take an example, consider how few persons of a normal standard of education could sketch, with the haziest approach to accuracy, a picture of the Europe with which Cromwell had to deal, or contrast it with the Europe which Napoleon started to reconstruct. Then think how little terrors such a question would have for anyone who had glanced at two half-pages in Mr. Ramsay Muir's atlas. On one side he would have seen, the date being that of our English Restoration, three of the great continental powers of that day—Sweden, Poland and Turkey—holding between them a solid block of territory stretching from the Arctic Ocean to the Mediterranean, which shut Russia off from the sea and out of Europe, dominated Prussia and dwarfed all the modern States of Central Europe. On the opposite half-page he would have observed that, when

Napoleon came on the scene, Poland was dismembered and no longer on the map, Sweden and Turkey were maimed and shrunken, and the three great realms of Russia, Prussia, and Austria were overshadowing Europe. Let a person of the most moderate intelligence get those two vignettes into his head, and the framework for nearly a century and a half of crowded history is at his command.

It is of course by no means only, or even mainly, of its cartographic or diagrammatic functions that we think when we try to press geography into closer touch with history in our educational system. Geography and its first cousin economics have very largely shaped history, and without some knowledge of them the study of history is liable to be both arid and misleading. That is a truism to which it will be convenient to return later. A consequence of it, however, at which it is worth while to glance in passing, is that geography has much to teach to those who are actually making history to-day, and equally merits attention by those who fill the useful rôle of critics of the makers of history. We are frequently told that a little knowledge of geography would have been of advantage at Paris while the Peace Treaties were being negotiated in 1919–20. Possibly so ; but a bowing acquaintance with geography would not be out of place in the multitude who find it so easy to pull the treaties to pieces. I say nothing about the Polish corridor. For various reasons we may fear or even dislike it ; but geography jogs our memory as to the long history of Poland's wide access to the sea, and as to the isolation in which East Prussia was born and prospered. A less simple issue is raised by the energetic and expensive propaganda now being carried on for a revision, on ethnological and geographical grounds, of the new boundaries of Hungary. The ethnography of the Succession States of the old Habsburg Empire may well puzzle the wisest of us ; but the framers of the Treaty of Trianon were certainly not ignorant of geography. It is one thing to claim that the broad plain between the Tatra range and the Danube eastward of Bratislava is Magyar in culture. It would have been a very different matter to include that fertile area in the borders of Hungary ; and the prosperity which has come to Bratislava and Komarom, in spite of racial grievances, is some tribute to the geographical basis of the new boundaries. Further east, still along the Danube, there were racial arguments for leaving a slice of Carpathian Ruthenia in Hungary ; but the result, to quote Dr. Seton Watson, would have been ' to cut the natural communication between a long series of valleys, to cut off the hinterland—one of the poorest and most neglected districts of the old Hungary—from the plains which produce the food, to leave Ruthenia without railways, and to destroy the railway connections between Czecho-slovakia and Roumania.' These are minor but pregnant instances of the value of the large-scale map in the making of history.

Having now glanced at several sections of the perimeter of our field, we have found in each of them one definite pointer towards the centre of interest which is common to them all. Prehistoric geography attracts us by reason of its mystery and romance ; but the romance lies in the fact that the grim powers of nature—oceans, volcanoes, sinking continents, towering glaciers—were all co-operating in the slow preparation

of a surface for our globe on which life can exist. When we come nearer historic time, we think of geography in terms of a medium in which at least primates can multiply and move, and in which ultimately *homo sapiens* can establish abiding places for his different families. If we then turn to physical geography, we are thinking mainly of how the forces of nature can be observed and calculated in their action upon the habitable globe ; in other words, in what measure they are tending to make it more endurable or less endurable for human beings. Lastly, when we come to political geography, we are concerned frankly with, and only with, the distribution of the habitable area of our planet among the various groups of men and women who call themselves nations. It is the human aspect of geography which is permanently in the background of all its sections ; and the essential scientific value and interest of geography lies in the part which it plays in preparing and furnishing a home for mankind. Of what interest or value to us would be the geography of the Milky Way, or even of the Moon, so long as we know of no life which it would influence ? and is not our sporadic excitement about the geography of Mars aroused solely by our curiosity as to whether the changes observable on that planet are, or are not, the work of hands and intelligences somehow akin to ours ?

IV.

Thus we arrive at what seems the predestined centre of the field, at geography which has no adjectival label, and which one would hesitate even to call human geography, lest there should thus be conveyed some suggestion of implied antithesis. It is the study of geography as the science of man's physical framework, his home, the material for his existence. Seeing that all life lives together, what we are really thinking of is not man alone, but animals and plants as well. By the inclusion of these, however, the area to be surveyed becomes so vast that I cannot touch to-day on those parts of the field which are of special interest to the zoologist and the botanist. They have their own entrée to our science, but in a sense so specialised that the ordinary amateur geographer has no qualifications for discussing it. Taking human geography therefore as exactly what its name indicates and no more, we find in its lay-out the whole study of the relations between man and inanimate nature. If this round globe had a voice which we could hear, and if it cared to use our language, it would probably describe our theme as the study of a tiny and prolific parasite upon its skin. We naturally think better of ourselves. Our study is one of actions and reactions ; it investigates the reasons why the multiplication and distribution of man is influenced by geographical features, and on the other hand the methods by which man, reacting to those features, endeavours to modify them. It is the whole problem of environment and adaptation. As that eccentric but stimulating writer, Hendrik Van Loon, expresses it, ' the roots of any given people are situated deep in the soil and in the soul. The soil has influenced the soul, and the soul has influenced the soil.'

As on all other subjects on which students feel deeply, sharp differences

have arisen over the treatment of this human geography, mainly focusing, it would appear, on the order of precedence between environment and adaptation in time-space. It would be unbecoming, without knowledge of the arguments, to enter this arena; but I submit that some of the disputants have been a little severe in pouring scorn on the early exponents of the theme. Old Jean Bodin, it may be, did not see much beyond his nose when he divided the world into the cold zone of the stupid but vigorous democrats, the hot zone of the intelligent but lazy victims of theocracy or any other despotism, and the temperate zone occupied by happy France and its ideal monarchy. But at least he did some mapping out in his own way, just as Strabo had done in his, and he set men thinking. Then Buckle, if I may miss all the great names in the interval, comes in for a good deal of mild sarcasm. It is true that his famous chapter upon the influence of nature on man is marred by curious lapses; as, for example, when he professes ignorance of the cause why all the mighty rivers in the New World flow to its eastern coast, and none of them to the western; or again, when he lumps together the peoples of Sweden and Norway, and of Spain and Portugal, as being 'all remarkable for a certain instability and fickleness of character.' But, if occasional odd sayings like these are overlooked, there is much in his general argument with which at least one school of modern anthropologists must be in sympathy. That there is any radical or original difference between the various races of mankind, he regards as 'altogether hypothetical,' and the existing discrepancies he endeavours to trace to the influences of climate, soil and food. It must be admitted that, as his analysis proceeds, the promised explanation of racial differences evaporates, but there survives a review of political and social tendencies, in which there is little to challenge, especially when we remember that he is dealing exclusively with early societies. In such societies, he argues, the accumulation of wealth is largely a matter of climate and soil; with wealth comes leisure, and with leisure comes civilisation. Hence civilisation appeared first in those lands where nature unaided begat wealth—in India, Egypt, Peru and Mexico. But where food is abundant and cheap, population tends to increase unduly, and the standards of life deteriorate. Thus, in countries where climate and soil are favourable and food is 'provided by nature gratuitously and without a struggle,' wealth has always abounded, but it has been unequally distributed; and consequently there has been no just division of political power, no democratic spirit, but only despotism in the upper, and 'contemptible subservience' among the lower orders. Progress accordingly has been insecure and society unstable; natural decay has set in, and the invasions of sturdier races have completed the tale of doom.

As a philosophic survey, there seems no patent absurdity in all this, though it sounds somewhat elementary now; and the argument is relieved by telling patches of colour, as when Buckle describes how the alluvial wealth of Southern Asia transmuted the roving savages, the wandering shepherds of Arabia into the cultured monarchs of Cordova, Delhi and Baghdad. An even finer passage is that in which he distinguishes Brazil from other countries where nature is generous with her gifts. In the

flow and abundance of life, he writes, 'Brazil is marked above all the other countries of the earth. But, amid this pomp and splendour of nature, no place is left for man. He is reduced to insignificance by the majesty with which he is surrounded'; and so on. Finally we reach an argument which is independent of any purely literary charm; it comes when Buckle leaves climate, soil and food, and speculates on man's sensitiveness to what he calls the aspects of nature. They fall into two categories, those which excite the imagination, and those which address themselves to the understanding. In countries where the former abound, in the shape of mighty mountains, earthquakes, or devastating pestilence, man is conscious of his own unimportance, and the powers of nature fetter his will. Where, on the contrary, nature is gentle in her manifestations, man regains confidence and exercises authority. Buckle takes India and Greece as types of the two extremes. In India the tropical grandeurs and perils have led to an uncontrolled ascendancy of the imagination, which runs riot in its literature, its art, and its theology; fear governs men's minds and the gods are monstrous. In Greece, at the opposite end of the scale, nature is friendly, and the imagination quickly loses its supremacy. Reason gains dominion, superstition dies, and the enquiring and sceptical faculties of the understanding are cultivated. A touchstone, Buckle suggests, is to be found in hero-worship: the canonisation of mortals soon became a recognised part of Greek religion; while in India the whole tendency was to widen the distance between men and their deities. From this pregnant series of contrasts he concludes that 'everywhere the hand of nature is upon us, and the history of the human mind can only be understood by connecting with it the history and the aspects of the material universe.'

V.

In this summing-up we may all agree. Generalisation is a seductive and flowery meadow, but it is studded with pitfalls, and into several of these it may be that Buckle, with all his erudition, stumbled. Nevertheless is there not wide scope for investigation into the rôle which geography plays, at first in shaping religions, and afterwards in maintaining morals? This very contrast to which we have just been listening between Greece and India is full of suggestions. Wherever it was situated (and this probably we shall never know), there was assuredly one common ancestral home for the main gods of Olympus and the earlier occupants of the Indo-Aryan pantheon; on this point the evidence of philology is conclusive. The possibility is that, in the region where they were first worshipped, those divinities were the great natural phenomena, which man, as soon as he learned to think, watched with wonder and reverence: the Sky-father, the Earth-mother, the Sun, the thunder, the fertilising rain-cloud. Most of these survived into Greek mythology, but it was very largely mythology. They had come down from some ancient cradle of the race as a part of its culture. They were honoured by shrines, by sacrifices, and offerings on festive occasions; but they were never the object of fear. In that land of clear air and sparkling sea, there was no gloom about the temples. The deities in time were personified, moving

like men and among men, with similar passions to men. The Greek artists fashioned their statues in the form of men and women, supreme only in their grace and beauty. Poets narrated their conversations and sang of their quarrels. Gradually, alongside the formal national rites in their honour, the impish popular wit began to fasten upon them. Jupiter's infidelities, Juno's jealousies, Mercury's petty larcenies, Vulcan's stupidity, Cupid's mischief, finally scattered the idea of awe, and the Greek mind was liberated to reason out for itself the problem of existence and the canons of right living. In all this geography undoubtedly had a hand. Her peculiar mountain system had divided Greece into a number of separate little communities, allies at times, enemies at others, but always vigilant for their physical fitness in the defence of their home cities. Her extensive and sheltered seaboard brought to her doors all the busy intellectual life of the Mediterranean world. With athletic bodies, sane and alert intellects, her children had no room for superstitous fears of the unknown, and they laid the foundations of modern scientific thought.

Into India virtually the same theogony had been imported by the Indo-Aryan invaders of two or three millennia before Christ. But into how different a world they came. Isolated by gigantic mountain ranges and stormy oceans from her neighbours, India had very little living contact with the thoughts or interests of other lands. Within her borders the workings of nature were hard and often cruel. Drought and famine at periodic intervals swept off their thousands and their hundreds of thousands. Diseases attacked the land in mass formation ; so did flood, earthquake, tempest, everything against which man is powerless. Beasts of prey swarmed, and no humble home was safe from snakes whose sting was inevitable death. The landscape, too, had its times of grimness, as those of us know who have lived in the plains through Indian hot weathers. The hills were awe-inspiring rather than friendly, and the forests held particular dread for those early simple people. In this environment the gods soon lost all human touch. The first Veda had addressed them in stately and reverent hymns ; but its strains were foreign to the soil and were never renewed. The Hindu pantheon became a huge gallery of godlings and goblins, in which the heavenly beings of the primitive Aryan stock got for the most part changed into objects of terror to be propitiated and, whenever possible, avoided. The cult of Krishna, it is true, shows how the human heart yearns for a divinity which is consoling and kindly ; but Sri Krishna's observances are only a brief interlude in the gloom of India's religious life. The representations of the gods in statuary and painting are deliberately monstrous, as if to mark their distance from man, and to our western taste almost always repulsive. In tracing this connexion between the rigours of nature and the severity of men's creeds, I would not be taken as ignoring that side of India's mind which strives daringly to plumb the unknowable. In pure metaphysic it is possible that India has something to teach to lands where geography is kinder ; but here again the vague mysticism of her speculation has some analogy to the vastness of her plains and the inaccessible sanctuaries of her hills.

If we turn to two other great religions, Judaism and Islam, is it altogether fanciful to surmise that geography has been directly concerned in their development? Their central idea is the oneness of God, not as a universal soul, but a solitary, omnipotent and jealous power. We are told by scholars that Judaism in origin was the triumph of one tribal god, Jehovah, over a number of other rivals. It is not implied, as I understand, that the individual tribes were polytheistic, though each had its own name and attributes for its own protecting deity. Be that as it may, the conception of unity was paramount among the Hebrew stock; and it was militantly re-stated by Mahomed. Why did unitariansim so fiercely possess the mind of Arabia, to the exclusion of the more complex creeds which permeated the rest of Asia? The Semitic spirit will hardly furnish the explanation, because it has not always and everywhere been incompatible with idolatry. It is in the daily life of the desert-dweller that we must look for the reason, in its solitude, its stern simplicity, its concentration of thought and purpose on the business of the moment. There is no room for the luxury of polytheism, and no time; furthermore, the unity of surrounding nature postulates the same quality in the Creator. With other religions the case may not be so straightforward; and I am not sure how far it is possible to pursue the same line of thought into the great reforming movements of the world. Buddhism, for example, presents a curious problem, with its complete disappearance from the land of its birth and its fervid acceptance in other geographical areas. Or, coming back to Europe, we have the familiar theories as to the spread of Calvinism and the present-day distribution of Protestantism and Roman Catholicism. The ground, however, is too delicate for an amateur geographer. There is also very little left of the raw material for such enquiries. Our modern creeds cross oceans and capture new territory, just as our modern languages do, with more reliance, let us hope, on their intrinsic merits than on geographical considerations.

VI.

The last section of the survey through which we have been scampering is human geography on its material and practical side. Here we study nothing less than the eternal conflict of nature versus man,—the rôle which Michelet assigned, though not convincingly, to history. Often it is a real conflict, with times and places at which nature defeats man, with others at which man gains, or seems to gain, the victory. Often, and more often as civilisation advances, it settles down into bouts of diplomacy, where man endeavours to get on terms with nature. Geography, if he understands it, helps to tell man where defeat has hitherto been final, where victories can be snatched, how relations of mutual aid can be established. Moralising in a general way on individual instances, it would point to the Alpine barrier, which at first protected Rome from the north, later admitted the barbarians, and then for centuries complicated Italy's connection with Central Europe, until engineering skill bored holes through it and cleared away many of the old troubles. Or it would tell how the Appalachian barrier for long dictated the lines of

colonisation in North America, pinning the English settlements down to the Atlantic coast, and leaving the Mississipi valley open to the enterprise of the French. Or, harking much further back, it would point to an older barrier, the tumbled hills and impenetrable forests running across the Indian peninsula parallel to the Nerbudda valley, which protected, it may be for a thousand years, the Dravidian culture of the south from the invasion by Indo-Aryan influences. As types of whole nations which have had to wrestle with nature, it might single out Spain and Holland. Spain, after the melting away of its oversea dominion and the decay of its prestige in Europe, unconsciously surrendered to its geographical position. Sheltered behind the Pyrenees, it showed a disposition to cut itself out of European politics ; partitioned into unconnected sections by intractable mountain ranges, it has allowed the same habit of local dissension, which rendered it an easy prey to the Moors, to divide its people and weaken its national life once more. Holland, on the contrary, typifies a stout refusal to surrender to nature. Its people, undismayed by losing their former command of the High Seas, turned upon their own sea and ejected it ; so that they have transformed into a rich agricultural and industrial land what was once a vast expense of tidal marsh and fen, and they are still doing it.

These are only haphazard incidents in the age-long contest. The chief purposes of human geography are to record how the forces are arrayed to-day, and to help in the intelligent estimating of how they will sway the future. The materials for its task are the extreme diversity of nature on the one hand, and the unity of man on the other ; for it must deal with the family of mankind as a whole, and with their needs as a whole : a home, food, and clothing, and the labour on nature's products by which they earn their shelter and their means of existence. As it stands on the threshold of its modern task, geography has to sound its trumpet and call in the support of its bordering sciences, geology, climatology, botany and all the others, but most especially of one which has not yet been mentioned ; for only with their help can it succeed. How it will prosper in its endeavour is the responsibility of our educationalists ; and it is no small satisfaction to know how far they are prepared to go in giving our new science its appropriate place in the teaching curricula of our educational system. But in that direction there is still much to be done. For, in order to fit geography more usefully into the mental equipment of educated men and women, it seems that the problem is to secure a new emphasis on the physical features of our globe, so as to give them an organic and dynamic, rather than a tabular and static, value.

If we think of the world as an abiding place and study the geography of any one country first from that point of view, it does not satisfy us to know the names of its chief towns and rivers, or of its mountains, capes, and bays should it happen to possess any. Each city has some individuality, and a dossier of its own, into which we should like to peep. There is something to tell us how it came into existence, whether it is growing or decaying, what keeps it together, what is its racial, political, or commercial importance ; in short, why men built it, why they live in

it, and what they do. We should also, if time permits, be interested to know something of its story in the past, what men in it have fought for, whether it has often changed hands or creeds, and such personal details as to why we call it Oslo when it was once Christiania, or why old St. Petersburg is now Leningrad or whatever its name is to-day or may happen to be to-morrow. When we get outside the cities, the countryside also has its tale. Is it agricultural ; and if so, what is the pressure of population on it ; or is it mainly a land of manufacturing activities ? How much of it is unoccupied, and why ; has it been converted into a home for grouse and stags instead of hardy crofters, or has man been warned off by malaria or the tsetse-fly ? If the next chapter of our study is the sustenance which the country offers to man, we find a great deal to discard in our old authorities, and much investigation to be undertaken with a fresh mind. In the matter of climate, for example, we must get rid of our smug statistics of average rainfall and mean temperature—among the most misleading data which pseudo-science has ever invented. The climate of the country which we are surveying will require a more intelligent, though not necessarily an elaborate, estimate. So with the soil, and the fertility of its different areas ; its irrigation if the rainfall needs supplementing, and the facilities for artificial irrigation. Thence to the produce of the soil is an easy step, though here also discrimination is advisable. Rice may be grown which the indigenes can eat, but which it would be useless to export because it is unsuitable for milling ; or cotton which its growers can use, but with so poor a staple that no manufacturing country will look at it. The agricultural output as a whole needs more sympathetic treatment than our text-books often give it. The same may be said about the mineral products, especially coal ; and the careful student will watch the opening for the development of electrical energy, which we must continue to get from either fuel or water until Faraday's great-great-disciples discover how to extract it from sunbeams or the circumambient ether. Another step takes us to the manufacturing features of the country. What are its industrial centres ? To what extent are its manufactures rooted in the soil, or due to other special causes, or merely fortuitous ? It will be increasingly important to discriminate between industries with definite local advantages (like shipbuilding on the Clyde) and industries at the mercy of foreign competition (like jute in Dundee, and now cotton in Lancashire). Is the necessary labour available among the adjacent population ; are wages high or low ; can labour be imported if required ? Finally, how does nature help or hinder the marketing of the output ?

The last question brings up the whole problem of transport, the third point of view from which the geography of the country has to be studied ; and here the co-operation of nature and man has a sphere particularly its own ; especially in the navigation of great rivers, a subject on which the ordinary reader is often profoundly ignorant. Whether nature co-operated, or was defeated, in the matter of the Suez and Panama canals, is little more than a dialectic point. The important fact is that transport is (as indeed it always has been) in a state of transition ; the advantages

which it confers are constantly being bestowed here and confiscated there; and a vigilant geography is possibly more essential at this point than at any other. It is true, says Chisholm, that man cuts through an isthmus if it is in his way; but geography determines what isthmuses to cut, and deploys the local conditions which man must understand before he decides to act. Railways are amenable to the same set of considerations; so are harbours: geography has a powerful say in the alinement of the former and the location of the latter. Many generations may not pass before transport by air has revolutionised all this, and left our railways and highroads as curiosities in the same category as our English canal system to-day. But, like the free extraction of electrical energy, this is a contingency which we can leave geography to deal with when the moment arrives. Meanwhile it should be teaching us something of what has been done to make transport easier and shorter, and pointing the way to further advance in the same direction.

If commerce and industry, the lifeblood of the progressive races of mankind, are becoming more and more dependent on sound geographical knowledge, is it heresy to step down for an instant, and suggest that geography might also help man to enjoy his life? In one of the latest manuals on the United States, it was refreshing to find an enthusiastic page about the Yellowstone Park and the Grand Cañon. Might it not be possible, in text-books on our own land, to hear a little about the Scottish highlands, or the Welsh mountains, or the Cumberland lakes? And generally, would it be practicable, without poaching on Baedeker, to touch here and there on the beauty spots of the world, or even to mention, in passing, a great picture-gallery or a famous shrine?

Let me, with apologies for this lapse into æsthetics, return to the country in which we were asking geography to tell us something of its residents, its primary products, its industries and its means of transport. It is not the only country in the world; and by the time that we have pursued similar investigations for its neighbours, we shall have reached two incidental conclusions of some importance. One is the intimate alliance which must be established between geography and economics. They have become sister sciences. On its commercial side geography's kinship with economics is just as close as it is with geology on the physical side; the only difference in the relationship being that, whereas on the structural side of its work geography builds upon data provided by geology, on the human side it may very well, without loss of self-respect, engage itself in furnishing reliable material for the economist. The second conclusion is borne in upon us as we study the movements of population, the changes in industry which are liable to throw whole divisions of the labour army out of employment, the competition for markets, and all the struggle for existence on the earth's crust. They suggest that geography may become a more useful agency than hitherto for locating danger-spots in the world from the standpoint of international peace. There are plenty of Naboth's vineyards in our midst, and an intelligent study of geography should help to identify at least some of them, and to warn in time whatever organisation the nations may entrust with the policing of our unruly humankind.

VII.

I must now bring my rambling tale to a close. It has been a plea, not to a converted audience like this, but to a sceptical and on the whole an older generation, that geography is entitled to the full honours of a science. To the objection that it has to borrow so much of its raw material from other sciences, the answer is that the material is already there for the service of human knowledge generally, just as mathematics is at the service of astronomy, or physics and chemistry at the service of geology. Moreover, there is none of the bordering sciences which is prepared to undertake the tasks and fill the rôle of geography. Its positive claim is that, while always indenting freely on existing sources of knowledge, it is building up for itself, sifting and classifying, a body of knowledge which is found nowhere else, and which has a unity of its own and a purpose of its own. This process, we claim, raises it definitely to the dignity of a distinctive science.

Its unity is not impaired by the variety of its interests, some of which we have been cursorily surveying. Like many a family that is only lately ennobled, it can assert a respectable antiquity. It may not be able to produce maps showing the exact conformation of the earth's surface in the ages when it was occupied by the mammoth and Neanderthal man ; but, from the teachings of geology, it can deduce approximately the position of land, water and ice-caps at the time when the races of mankind were in their cradles ; and, keeping abreast of geological change, it can guess the routes of their subsequent migrations. It can bring the moulding of the habitable globe, with reasonable certainty, down to our own day ; and the careful geographer can record the surface changes which are now going on, and estimate their force and their pace. Alongside of those changes he will examine the physical influences which make certain portions of the earth suitable or unsuitable for human occupation, as well as those which facilitate or obstruct the intercourse of mankind. Geography will then carry us into the detailed investigation of the settlements of mankind, with reference more particularly to their national groupings and needs. Here, hand in hand with economics, it will explore the manner in which the various countries of the world are used for man's habitation, and under what conditions of life and labour and productivity they are occupied. Finally, geography in its hours of leisure may tell us where to see the supreme glories of nature, and in its more serious moods it may warn the League of Nations where to expect those causes of economic and territorial friction which imperil world peace.

Through all this diversity runs a golden thread of unity, in the human interest which binds the whole story together. Geography is essentially the science which treats of man's home, and the steady adaptation of the surface of our globe to be his dwelling-place and his workshop. And just as geography has its essential unity, so also is it transfused by a common purpose, the study of the relations between man and nature. If to this it can add—and why not ?—the ambition to help in improving those relations, then we complete its scientific purpose by associating with it a moral aim. Thus, at the risk of wearisome repetition, it is claimed

that we have the assemblage, the testing and the analysis of facts, with a unified direction and a definite practical aim, which amply respond to the definition of a science. And to the three criteria which the ordinary man expects science to satisfy, geography presents a ready face. As a training for the intellect, it does not rely on balances, test-tubes, mathematical formulæ, and the like; but it answers Dr. Whitehead's desideratum in being a process of measuring rather than of classifying; and it is an adequate school for exact observation and wise deduction. As a contribution to the solacing spirit of humanity, its work in removing misunderstandings between peoples and forestalling friction may become increasingly valuable. And as a mental equipment it yields to none of the kindred branches of knowledge. Apart from its importance to the traveller and the student of international affairs, it is essential to the economist. Not less so to the historian; you have only to compare Trevelyan's account of Marlborough's campaigns with most other narratives of the same events, in order to see how an acute appreciation of the geographical setting of warfare is powerful to convert arid prose into a living picture. Lastly, without geography the statesman is liable to grievous error; and it is indispensable knowledge to the practical industrialist and the planner of big business.

Feeling as we do on the subject, can we expedite the advancement of geography to its proper place in our educational system? It was for the purpose of evoking discussion on that question that I ventured on this address, speaking as one who learned nothing about geography in youth, and who realises the handicap. Since Oxford and Cambridge formally recognised the subject forty years ago great strides have been made. Perhaps the most encouraging advance is the growing attention to regional studies, to what Dr. Bryan calls the cultural landscape. It is a landscape, as he shows us, upon which each one of us looks out every morning of our lives; and its very familiarity may have led in the past to its neglect. But on the steady advancement of this regional work, if we can only get its methods properly taught, will depend the future of the science. Meanwhile the foundations for it have to be laid in the elementary and secondary schools, and it is here that we still find blind spots in the national outlook on the advantages of the systematic teaching of geography on modern lines. At a recent exhibition held in this city a remarkable demonstration was given of the remedies which are being applied; and in other directions, especially in the admirable character of some of our newer text-books, there are signs of better things coming. The time is ripe for a combined forward move; is it possible for our meeting here to provide the necessary stimulus?

In conclusion, may I offer this Section E my most grateful thanks for the high honour they have done me in electing me their President for the year, and my heartfelt apologies for the poverty of my response.

SECTION F.—ECONOMIC SCIENCE AND STATISTICS.

THE GOLD STANDARD

ADDRESS BY

PROF. J. H. JONES,

PRESIDENT OF THE SECTION.

When the Association, through its representatives, conferred upon me the honour of electing me President of Section F for the current year, I felt that the subject of the Presidential Address was determined for me by the present state of affairs in the world. Currency stability, broadly defined—or, better, undefined—is a condition of economic and social progress. The outstanding problem of statesmanship is to restore that stability which the world enjoyed before the outbreak of the recent war. I believe that the causes of present instability and the conditions of future stability can be described without the introduction of technical terms likely to bewilder those who are not professional economists. I therefore felt it to be my duty to devote my paper to a discussion of the gold standard and to address the lay rather than the professional section of the audience. I shall begin with a very brief survey of the past.

I.

Before the war of 1914–18 the gold standard was among the things taken for granted as an element of western civilisation. It had served England for nearly a century. The echoes of the bimetallic controversy on the continent of Europe had already died away. It was a controversy that belonged to the nineteenth century. The silver question had ceased to be 'spot news' in the newspapers of the United States of America. The spirit of nationalism in currency affairs was on holiday. When, in the last three decades of the nineteenth century, one country after another joined the gold standard group, their action was held to be a sign of progress and they seemed to hold their heads higher than before. They acquired prestige. It was thought that in the Far East the process of industrialisation would be marked—as, indeed, it had already been marked in India and Japan—by a transition from a silver standard to a gold standard adjusted to national conditions.

An unvarying price average was not, however, among the achievements of the gold standard. For roughly two decades before the Franco-Prussian war, the so-called general level of prices had risen under the

influence of an increase in the rate of annual supply of gold following upon the Australian and Californian discoveries. The post-war boom, which reached its greatest height in the winter of 1872–73, was followed by a downward trend which, if measured from the top of the boom to the bottom of a depression, continued for approximately twenty-three years. This trend in prices is usually attributed to a fall in the rate of annual supply of gold, but I believe it to have been due, in greater measure, to a rapid increase in the world demand for gold required for monetary purposes. It covered the period during which the gold standard became popular. One after another of the silver and bimetallic countries transferred their allegiance to gold. The United States returned to gold after several years on a paper standard. New territories were exploited, and the respective Governments adopted the gold standard. The world demand for gold reflected the process of transition ; it grew far more rapidly than trade and population, and more rapidly than it could be expected to grow under any other conditions or at any time in the future.

By the end of the century practically the whole of the modern industrial world was on the gold standard, and from that time forward the standard was free from the complications and dangers created by the appearance of new disciples. It had become, to all intents and purposes, a world standard. It could be judged on its merits as an international standard. For the time being the countries that had not yet adopted it could be regarded as relatively minor exceptions. The growth in the demand for gold would be expected to keep pace with the growth in population and in trade per head. During the remainder of the period ending in 1914 there was a fall in the relative amount of gold needed as money. Not only was the banknote increasingly employed in ordinary transactions, but in English-speaking and other communities the cheque or its equivalent was growing in popularity. While on the one side the rate of increase in the demand for gold was affected by the cessation of the march of nations towards the gold standard and the growth in the use of substitutes for gold coins, on the other the rate of annual supply was increased by the development of the South African gold mines. For these reasons the downward trend in prices came to an end about 1895 or 1896 and was replaced by an upward trend which continued until the outbreak of the world war and the suspension of the gold standard.

The rise in prices during this period was not acceptable to everybody. The lag in wages caused serious discontent and probably hastened the growth of national organisations capable of much good but also of serious harm. Forces were being generated which have materially helped to shape economic and social events since the war. But the period of rising prices was also one of rapidly developing trade and relatively high profits. The discontent was that of the employed worker rather than, as at present, of the unemployed worker. The former might complain of inequalities in the distribution of wealth, but he could not complain of the pernicious effects of 'deflation.' As the gold standard permitted a steady increase in the supply of money, and a rise in prices, the arguments now frequently employed against the gold standard would have sounded foolish. The standard itself was enjoying a respite from popular criticism. In its

broad sense it was accepted on all sides as not merely inevitable but also desirable.

Then came the war, with the usual economic consequences of war. The gold standard was abandoned by nearly every country and currencies were left to the mercy of needy Governments. The inevitable war-time inflation was followed by the customary post-war boom and the process of inflation was carried a stage farther. The subsequent period of depression and falling prices imposed a searching test of economic policy and revealed the degree of exhaustion from which the various countries suffered. Currency instability and trade depression were associated in the minds of people as cause (or part cause) and effect. It was assumed that if and when currency stability was restored the world would have a chance of recovery: without such stability recovery was impossible. It was known, even at that time, that stability was a term that begged most of the questions at issue, but such a detail was of no consequence at a time when people longed for the restoration of pre-war conditions. The world that disappeared in 1914 appeared, in retrospect, something like our picture of Paradise. The financial leaders were strongly supported by public opinion when they pressed for a return to the gold standard.

The world returned to gold. The defeated countries, whose currencies had been destroyed by inflation pursued to its logical end (though not in obedience to logic), created new currencies linked to gold. After ' looking the dollar in the face ' for a couple of years we restored the gold standard in 1925 at the pre-war rate. In the following year France and Belgium stabilised their currencies in relation to gold and in 1928 restored the gold standard, France fixing her currency at about one-fifth the pre-war gold value. Meanwhile most other countries had joined the gold standard group. Within the space of four years the gold standard had been restored, and it remained in office—though not always in power—until 1931, when it was again destroyed. From 1924 to 1929 most of the currencies of the world were stable, and the economic world made rapid progress, although, for reasons that will presently be noted, Great Britain did not enjoy a reasonable share of that progress.

The depression in trade after 1929 imposed too heavy a strain upon our own country and in 1931 we again suspended specie payment. Our example was followed at intervals by a large number of other countries and now the world is divided into two parts, the group of countries that have abandoned the gold standard and those that still, in fact or in theory, have clung to it. When, a few months ago, the United States joined the former, it became evident that the influence of gold was weaker than it had been at any time since the war.

In this country the gold standard had appeared to act as a strait-jacket. The paper pound had been given such a high gold value that our freedom was severely restricted. In spite of pessimistic predictions before the step was taken the feeling engendered by the suspension of gold in 1931 was one of newly found freedom. The fall in the external value of our currency actually stimulated trade. We found, however, that we were merely enjoying a larger individual share of a diminishing total.

And other countries discovered that they could, with advantage, join in the game of ‘ beggar-my-neighbour,’ which France had been quietly playing for several years and we had begun to play in boisterous fashion. Then followed the new practice of ‘ competitive depreciation ’ with the aid of instruments euphemistically called ‘ exchange stabilisation ’ or ‘ exchange equalisation ’ funds. Before this new practice spread we were enjoying our new freedom. Gold was a ‘ fair weather standard,’ to which we were in no hurry to return. America wanted us to return to gold, but why should we rush into new danger ? Disillusionment came when the United States (and therefore Canada) joined in the new game. The most recent experience, with new and strong players, has led us to believe that, after all, the game is not worth the candie, and that what we had termed a strait jacket was merely that sort of discipline which is a condition of freedom. The gold standard promises once more to become popular.

II.

The brief survey that I have submitted suggests the need for a restatement of monetary theory. In spite of all that has been published in recent years I do not believe that the monetary standard has yet received adequate treatment as a separate problem. In most cases the discussion of the standard has been more or less incidental to the discussion of other problems that either appear more urgent or are regarded as the central theme of the writer. Naturally I do not propose, in this paper, to attempt to fill the gap. But I venture to attempt to place before you those issues which, in my opinion, can be appreciated by the general public and must be faced if we wish to restore and afterwards maintain the gold standard in this and other countries. Moreover, I shall submit reasons for my belief that we should again seek to establish that standard, and that some modifications recently suggested would tend to weaken rather than enhance its value as an instrument of social progress.

Money is the means by which we secure ownership of things that we desire, or obtain services of various kinds. The amount of money paid for goods and services is the result of bargaining between buyers and sellers, and this result is influenced by certain fundamental considerations. One of these is the connection or sympathy that normally exists between the rates of payment (which I shall call wages) prevailing for personal services. If a coal miner earned ten times as much as a railway worker everybody would know that there was some highly abnormal influence at work which would ultimately disappear. Relative wages are governed by silent and persistent forces known to every student of elementary economics. They tend to arrange themselves around a mean wage in the manner determined by such forces. In a world of change the dispersion of actual wage rates at any time is never precisely that which the persistent forces tend to produce ; nevertheless the correcting influences are always at work. Again, the ‘ short period,’ during which deviations from the ‘ normal ’ distribution about the mean level may continue, tends to grow longer. The mills of competition grind slowly. But they con-

tinue to grind. We know that a rise or fall in the wages of one group will not be permanent unless it is followed by a corrresponding change in the wages of the other group, or unless there has been a change in the nature of the persistent forces to which I have referred. It is precisely this sympathy in wage movements that gives significance to the conception of an average wage and to movements in that average.

If it be true that the relationship between individual wages is not arbitrary, it is also true that the relationship between individual prices is not arbitrary. In the long run prices are governed by costs, and costs ultimately mean wages. Even economic rent, in the last resort, is a function of the wage average. If prices are governed by costs and costs by wages, and if relative wages obey a law of distribution, it follows that actual prices also tend towards a 'normal' arrangement or distribution. If a house of ten rooms could be purchased for the same sum as a hundred tons of coal, everybody would recognise the existence of some abnormal influence which could not fail, ultimately, to bring a correcting influence into play. A rise or fall in a large group of prices will not be permanent unless either a similar change takes place in the remaining group or a change has occurred in the real costs, and therefore money costs, of supply. It is precisely this sympathy in prices that gives significance to changes in the price average or general level of prices. As in the case of wages so, too, in the case of prices: the 'short period,' during which deviations from the 'normal' distribution may continue, tends to grow longer; but in the long run the effect of the persistent force of competition (broadly interpreted) becomes evident even in a constantly changing world.

These elementary facts seem to me to provide the true foundation of a theory of money. The supply of money needed by a community, and the supply of money that can be absorbed by a community, is a function of the price average. If every pound of wages or of prices were called ten pounds, the community would merely be using ten times as much money as before. Conversely, if the supply of money is fixed, the price average must conform to that supply, and in a state of equilibrium the wage average and the price average will reflect the normal distribution of individual wages and prices. But a change in the supply of money produces intermediate effects before the final state of equilibrium is reached. Nor is it necessary to stress the practical importance of these intermediate effects, which will presently be considered. At the present stage, however, it is desirable to confine our attention to the characteristics of a community in a state of equilibrium in the sense of being free from the intermediate disturbances of a process of change.

I have referred to the existence of a normal distribution of wages and of prices. The statements that I made are applicable to every community in which order is maintained, either through the force of competition or by legal enactment. But the normal relationship of wages or of prices is not the same in all communities: each has its own characteristics. Thus, for example, the relative rates of remuneration of school teachers, coal-miners and railway workers may not be the same, under normal conditions, in Great Britain as in Germany. The normal distribution may

vary, within narrow limits, even between different parts of Great Britain. The statement may be extended to include prices. Nevertheless it is true to say that for each community there exists a normal relationship of wages and of prices towards which actual wages and prices tend. I assume this broad generalisation in all that follows.

My next statement is equally elementary. It is a truism that some commodities and services supply local markets while others supply national or international markets. In the market, whether it be local or world-wide, there is a strong tendency towards a common price. Within this country the price would be quoted in the same money, but in other countries it would be quoted in some other kind of money. If, however, we exported a commodity we would normally expect to be paid, in foreign money, an amount equivalent to the British money obtainable for it if it were sold at home. The means of payment may be some foreign money —we may, for example, accept payment in marks—but the measure of value is our own money.[1]

For the purpose of simplifying the statement I shall assume commodities (including services) to be divided into two groups, international and domestic, the former comprising those which are commonly exported from one country to another and the latter those which supply local markets. Further, I shall neglect variations in costs of transport. Finally, I shall assume that all communities or countries employ gold as money. It follows that international commodities command the same prices in all countries. British exports are sold at the same prices as German exports or American exports. But we have already seen that the prices of British exports are normally related to the prices of all other things produced and sold in Great Britain. Consequently the price average or general price level in this country will be such as to produce the international prices for international commodities, while the wage average or general level of wages will be such (under a normal distribution of individual wages) as to produce that price average. It does not, however, follow that the wage average in this country must be the same as in other countries. The wage average will be a function of natural conditions, industrial technique and human efficiency ; but it must be such as to enable the country to maintain the price average dictated by international conditions.

The same general truth may be expressed in another way. Gold, like other international commodities, is distributed among the markets (countries) of the world in such a way as to command the same value in all. Value in this connection means purchasing power. It follows that in the state of equilibrium represented by such a distribution of gold, the exports and imports of a country are balanced.[2] It must be so, for

[1] It is immaterial that, in this case, we accept the risk of exchange : it would be possible for us to cover that risk, and the cost of covering it would be a prime cost and a component part of the price in pounds. In a state of equilibrium there would be no such risk.

[2] It should not be forgotten that I am assuming exchange to be confined to commodities, including services. I shall presently refer to movements of capital.

it is evident that if exports do not balance imports there will be a flow of gold from one country to others. This flow will only cease when a true equation has been established.[3]

It will be clear from the statements already made that if all countries employ gold, and only gold, as currency, each must accept the wage and price average or level dictated by the price average of international goods, and that this will be determined by the gold supply in relation to the demand. If the gold supply is x the price average will be half as high as if the supply were $2x$, for in making such a comparison we may assume the rapidity of circulation to be the same in the two cases. Such a currency therefore imposes a discipline upon each country ; it must march in step with the others. If one country found a gold mine within its boundaries, issued currency to the amount of the new supply and raised wages and prices to the extent of the new available currency, exports of other commodities would fall and imports increase, with the result that the gold would flow out until a new equilibrium was reached at a correspondingly higher international price average. During the intermediate stages the industries supplying international commodities would be depressed in the country possessing the new gold mine, and correspondingly more active in other countries. This change in the state of trade would be the active force that would restore the new state of equilibrium.

It will also be evident that the same results will follow if, instead of using gold as currency, each country employs paper representing gold, pound for pound, or dollar for dollar, so that any variation in the supply of gold is automatically followed by a variation in the supply of paper currency. Nor is the case altered if gold represents not a hundred per cent. but x per cent. of the paper currency. For it is clear that a given variation in the supply of gold is followed, automatically, by a similar percentage variation in the supply of currency. Moreover, it is obvious that the smaller the percentage gold reserve (that is to say, the greater the economy in the use of gold) the higher the price average of international goods and the wage and price average within each country. But it remains true that each country is subjected to the discipline to which I have referred.

Provided one condition is satisfied, the case is not altered if, instead of merely employing paper currency the supply of which is automatically adjusted to the supply of gold, a country also employs means of payment, such as the cheque, the supply of which may vary independently of the supply of gold. The condition is that the country remains on the gold standard. The gold standard is a legal enactment to the effect that the legal tender of a country shall be convertible on demand into a specified

[3] In the complex economic system which I shall consider at a later stage, exchange equilibrium between two or more countries may be defined in either of two ways, namely, a rate of exchange which maintains a balance of payments and a rate which represents equivalence of price levels. These are not necessarily identical. In a changing world they are not even likely to be identical. Failure to distinguish between the two, and to state in which sense equilibrium is being employed, has clouded much recent controversy.

quantity of gold.[4] Its economic significance is that it maintains a fixed rate of exchange.

While a country is on that standard it is forced to adjust its price average, and therefore its wage average, to the international price average. So long as the currency is a stated proportion of the gold supply the currency adjustment to a change in the latter is automatic. But when such currency is supplemented by means of payment the supply of which is not automatically controlled, some other means of adjustment must be found. In modern communities the duty of adjusting the supply of money, in its broad sense, and thereby administering the Gold Standard Act, is entrusted to the Central Bank or some equivalent organisation. The Central Bank is given the right to issue legal tender, and the supply is always—though not necessarily—specified in relation to gold supply.[5] But there is no legal regulation of the use of other means of payment. Control is left in the hands of the Central Bank, and the instrument of control is the rate of discount, supplemented and made effective by open market operations.[6]

By means of the rate of discount, reinforced, when necessary, by open market operations, the bank is able to control the supply of means of payment and thereby to adjust the wage and price average to the international price average. That being so, control by law of the supply of legal tender is not inevitable. It may still be desirable, for it is usual for the discount policy of the bank to be governed by the supply of legal tender held in reserve and this, in turn, is determined by gold movements. Nevertheless it represents a stage in the evolution of the credit system rather than an integral part of a perfect system. It is even more desirable in other countries than in Great Britain. On the other hand it is clear that the proportion of gold held against currency may be materially

[4] In the English Gold Standard Act of 1925 it was provided that legal tender was only convertible into gold provided that the amount to be converted was not worth less, at the defined rate, than 400 ounces of gold ; but this provision was merely a safeguard against the use of gold for internal purposes, such as currency. The paper pound was declared to be convertible into gold at the rate of £3 17*s.* 10½*d.* per ounce of standard gold, that is to say, it was worth the gold contained in the pre-war sovereign.

[5] The precise methods differ in different countries. We favour a fixed fiduciary issue ; other countries favour a fixed percentage gold reserve. This difference is not fundamental. The former produces less violent reactions and therefore facilitates a steady adjustment. The latter tends to produce unnecessary fluctuations during a process of adjustment to a new state of equilibrium. The English method seems to me better than that employed in the United States.

[6] It is important to stress the fact that the Central Bank is not a free agent. It is entrusted with the duty of maintaining the gold standard, and its action must be guided by the need for fulfilling its obligation under the Act which defines the standard. Since 1925 the Bank of England has been criticised on numerous occasions for pursuing a discount policy which was regarded as inimical to industrial progress. I do not suggest that the policy of the Bank has always been above reproach. I do not, indeed, believe that academic economists usually possess sufficient information to justify comment upon current policy. It is clear, however, that much of the popular criticism of the Bank has been due to failure to distinguish between the necessities imposed by the Act of 1925 and the policy of the Bank in circumstances that allowed freedom of choice.

altered without prejudice to the present system. The latter secures an automatic adjustment of the internal price average to the international price average, and this may be done with a 30 per cent. gold reserve as effectively as with a 40 per cent. reserve. A change from the larger to the smaller reserve would permit a substantial rise in the international price level.

The discussion of the gold standard has been based, so far, upon an important assumption, namely, that trade between countries consists of the exchange of commodities, including such services as shipping. I have ignored capital movements and interest payments. On that assumption I have tried to show that, when countries are on the gold standard, their internal wage and price averages must be adjusted to the price average of international goods. In a state of equilibrium trade between the countries will be balanced, that is to say, exports and imports will be equal in total value. Within each country the wage and price averages will represent a normal distribution of particular wages and particular prices. If equilibrium is disturbed gold movements will follow. In practice the equilibrium between countries will quickly be restored through the adjustment of the internal prices of international goods following depression on the one side or, on the other, greater activity. But the resulting internal disequilibrium is not so quickly removed. Some trades are affected more quickly and seriously than others; some are sheltered, others unsheltered. Wage rates in the latter fall out of line with wage rates in the former. So long as this adjustment is delayed the intermediate effects will continue. But in the long run the condition of domestic disequilibrium will be changed and a new position of stable equilibrium reached, both within the country and between different countries.

In the next stage of the discussion it is necessary to consider the effects of capital movements. One of the commodities entering into the final price average is capital, which, for my present purpose, I shall divide into investment capital and liquid capital. It is well known that the price of capital is higher in new countries than in countries which, in the industrial sense, have reached maturity, and that the difference is greater than the measure of relative risk. Hence we find a movement of capital from older to younger countries, enabling the latter to develop more rapidly than they would be able to do without such assistance. Investment is an import (of bonds) which must be offset by an equivalent export of commodities. Other things being equal an investing country therefore enjoys an excess of current exports of commodities (including current services) over imports. We need not pause to consider whether foreign investment or the excess of exports is the cause, or which came first. It is sufficient to point out that, in a position of equilibrium, the price average within a country must again be such as to make the price average of exports equal to the international price average and that, for commodities (including current services), the average will be lower than it would be if capital were not being exported. But in due course the lending country receives interest, and the amount of interest increases annually. This inflow of interest neutralises a corresponding outward

flow of capital. By 1914 the interest receipts of Great Britain were apparently less than the amount of capital annually added to our foreign investments. Our exports of commodities (including current services) appeared to be less than our imports of the same kind. We were reinvesting abroad nearly the whole of the interest upon accumulated investments, but apparently we already needed a small proportion of such interest to pay for current imports. A debtor state which had ceased to borrow also possessed a surplus of commodity exports, the surplus being needed to pay the interest on accumulated debt. Such was the position of the United States of America before the outbreak of the world war.

The growth of long-term investment was normally so slow and regular that it did not destroy the internal equilibrium of the investing country. For short periods it might invest more or less than the commodity surplus representing the sum available for investment. But in such cases the balance of payments was maintained by the transfer of liquid capital. The investment operation was supplemented by a credit operation. Similarly, if for any other reason there was a temporary excess of imports or exports the surplus or deficit was removed by a movement of liquid capital.

It is here that we find the essential difference between investment capital and liquid capital. Investment might well be termed an industry resembling coal mining or cotton manufacture. It possessed (if we ignore cyclical fluctuations) a fairly constant market outside the country and had been built up slowly upon the assumption that the market was comparatively safe and likely to grow. Other industries, supplying the commodities representing the export surplus available for investment, had also grown up alongside the investment industry, their growth being based upon the assumption of continuity in the growth of investment. In short, investment was an integral part of the industrial structure and an influence determining the remaining permanent features of the latter. It was not an accident of growth or an occasional visitor. Continuity was of its essence, and if all foreign markets for British capital had suddenly disappeared, industry would have been reduced, for a time, to a state of chaos. Liquid capital, on the other hand, was employed, in different places and at different times, as an equalising factor. Its purpose was to restore or maintain temporary equilibrium when equilibrium had already been destroyed or threatened; to ease the restoration of true or stable equilibrium by reducing the intermediate effects of a process of change or the effects of some temporary disturbing factor. I shall endeavour to show that some of our most serious difficulties since the war have been due to the fact that the distinction between investment capital and liquid capital has lost much of its pre-war significance.

III.

The conditions that I have described in the second section seem to me an essential part of a secure foundation for the working of the gold standard. But they do not indicate all the conditions that must be satisfied.

In order that this may be made clear it may be desirable to indicate very briefly the features of the pre-war gold standard and the essential differences between the working of the pre-war standard and the working of the standard since the war came to an end.[7]

The pre-war standard was of slow growth and became the foundation of a financial system of a highly complex character regarded from the point of view both of structure and of function. The standard was adopted by one country after another under conditions favourable to its operation ; it represented a choice between three or more alternatives, and its adoption was regarded as a real advance. The first important point that I would emphasise is that the industrial structure had been adapted to the requirements of the standard. The normal level of wages, costs and prices was adapted to the rate of exchange and consequently to the international level of prices. The currency was neither overvalued nor undervalued, but neutral. The theory of comparative costs afforded a real explanation of the distribution of industry and trade between nations. Changes in the distribution of trade were slow and continuous and were due either to changes in the relationships of real costs of production or to changes in tariff policies. It is, of course, true that changes occurred in the relation of the gold supply to the world demand for gold and therefore in the international price level, but these were so slow as to present no serious obstacle to the adjustment of wages and costs in individual countries. In this connection it should be observed that gold was allowed to move freely from one country to another in response to economic influences and that movement was only due to such influences.

In the second place, the savings of the people were invested in long-term securities. A comparatively small amount was added every year to the fund of liquid capital employed in financing trade ; but this fund was determined by trade requirements and by the opportunities for long-term investment rather than by the willingness or unwillingness of their owners to invest.

In the third place, the long-term investments of lending countries, such as Great Britain, Germany and France, were appropriate to the industrial structures of both lending and borrowing countries. Thus, for example, the industrial structure of Great Britain and the annual overseas investments of Great Britain formed pieces which fitted together to form part of the economic mosaic.

In the fourth place, although most of the countries of the world were living under protective systems, and of systems of greater or less protection, tariffs were not employed to correct temporary failures to balance international payments during periods of depression. Protection represented a choice of alternatives and in each case the system was carefully thought out and determined by long-term considerations. For a relatively long period of years a protective system could be regarded as a

[7] I discussed these in greater detail in a course of four lectures delivered shortly before Christmas to the London Institute of Bankers and published in the *Journal* of that Institute.

constant; international trade adapted itself to that system and for this reason the system did not seriously prejudice the operation of the gold standard. This statement does not constitute a defence of protection.

Finally, the credit system of the world was not only firmly organised, but organised in such a way as to facilitate the working of the gold standard. The Bank of England acted not only as the Central Bank of Great Britain, but also as a sort of International Bank of Economic Settlements. In time of need it was able to draw funds from other countries and to employ those funds at the place of need and in the manner dictated by that need. One of the outstanding features of the system was that, when any country was in distress, the Bank of England was able and ready to mobilise the reserves of the world and to rush to the rescue of that country. Credit or liquid capital was thus a balancing influence rather than an influence employed to destroy an existing state of equilibrium. If actual gold was needed it was forthcoming, as in the case of the United States of America during the crisis of 1907; if a short-term loan was needed gold was not unnecessarily moved from one country to another; gold movements merely supplemented credit operations. Gold was not an alternative to a short loan, neither was it moved about in such a way as to necessitate a counteracting short loan operation. Both credit and gold movements were correcting rather than disturbing influences; they restored rather than destroyed equilibrium. The Bank of England adopted a more or less neutral attitude in the sense that it performed the essential functions of an International Bank and regarded the problem of monetary stability as an international problem. I do not, of course, suggest that its attitude was altruistic and that Great Britain voluntarily adopted such an attitude merely in the interests of world stability and progress. Such was not the case. The economic structure of Great Britain and the position that she held as the largest investing country and the centre of world finance made her individual interests identical with the interests of the world as a whole. There was no conflict, or presumed conflict, between the one and the many.

IV.

In all these respects the post-war world has differed from the pre-war world. Moreover, it seems to me that it is in precisely these differences that we find the real explanation of the failure of the gold standard, and that, before we can hope to establish any international standard that will stand the test of time, it will be necessary to restore those conditions which made the pre-war gold standard not merely workable but also highly successful.

In the first place, the post-war gold standard was not of slow growth. Most of the countries that had abandoned gold under the pressure of war rushed back within the short space of about four years, and without considering with sufficient care the changes that had occurred in the underlying economic conditions. The result was that in some cases the rates of exchange were fixed too high and in other cases too low. I may refer briefly to the two outstanding examples—Great Britain and

France. In 1925 we returned to the gold standard, and in doing so gave the pound the same gold value as it possessed before the war, that is to say, we restored the pre-war dollar rate of four dollars eighty-six cents to the pound. It was felt by many critics that such a value was too high in relation to the relative wholesale price levels of Great Britain and the United States of America. For several months before we returned to gold the dollar value of sterling had been rising, as the result of a transfer of funds to this country, without any change in the underlying economic conditions. Our price level, it was said, was appropriate to the dollar rate that prevailed before such transfer took place, so that in restoring gold at the pre-war parity the Government overvalued our currency, the extent of overvaluation being estimated roughly at 10 per cent. It was therefore necessary to reduce our price level by 10 per cent. in order to be able to supply international goods at the international price level.

It seems to me that that criticism was inadequate. After the boom of 1920 we suffered a period of severe depression during which wage rates in the industries supplying international goods (that is to say, the unsheltered industries) were reduced to an extent far exceeding the reductions that were made in the rates of wages prevailing in sheltered industries. In spite of these reductions the return upon capital invested in the sheltered industries fell below the normal rate obtainable in the sheltered industries. Thus we were already suffering from an internal industrial disequilibrium ; the normal distribution of particular wages to which I referred in the second section had been seriously disturbed. Although the wholesale price level for international goods was made, say, 10 per cent. too high by the return to gold, it represented a price level based upon an unduly low wage average in the industries concerned and an unduly low average return upon the capital invested in such industries. For that reason I believe that the degree of overvaluation was seriously underestimated by the majority of those who objected to the conditions under which we returned to the gold standard. The new standard imposed two tasks upon this country, the first being to reduce by 10 per cent. the price average or price level of the products of the unsheltered industries, the second being to make this new level represent a normal distribution of wages, costs, prices and profits throughout the whole of British industry. Even if there had been no other factor in the situation it is clear that an almost impossible task had been imposed upon the nation. But a further difficulty arose, after 1925, in consequence of a fairly steady fall in the world price level itself. In spite of the reductions in wage rates in the years that followed the return to gold, I do not believe that we succeeded in doing more than keep pace with the world price level. We had failed in the double task that had been set by the restoration of the gold standard.

The overvaluation of the pound inevitably produced a depressing effect upon British industry. It acted as a veiled tax upon exports and a veiled bounty upon imports, with the result that our export surplus was considerably less than would otherwise have been the case. At the same time the world was in need of capital and the tradition of London

as a centre of foreign investment led to an attempt to meet this world demand. British capital was invested abroad to an extent exceeding the available export surplus, but this result was hidden by the fact that during the same period other countries sent their liquid capital to London in search of security. I shall return to that point presently; at the present stage I wish to stress the fact that, if such funds had not been imported to this country, the underlying weakness of our position would have been revealed earlier. It would have been necessary to maintain even higher discount rates than those which prevailed and to pursue a policy of more severe deflation. The depression in trade would have been even greater than actually proved to be the case. This danger was averted by the importation of funds from other countries, although such importation created a danger of another character which will be presently considered.

The case of France differed materially from our own case. When, after a period during which the value of the franc was stabilised, the French Government restored the gold standard, the franc was given a value of approximately one-fifth the pre-war value in terms of gold. But the wage, cost and price levels in that country were such as to suggest a value far higher than that actually given to the franc. The result was that while in Great Britain the gold wage level was about 75 per cent. above the pre-war level, in France it was even below the pre-war level, and even at the present time seems to be little if any above the pre-war level. It is precisely for this reason that the French at the present time are able to contemplate with equanimity the prospect of a return to prosperity without any rise in the price level of that country. Further, the undervaluation of the French franc acted as a veiled bounty upon all exports and a veiled tax upon all imports. The temporary effect was to increase the export surplus (which was further increased by the receipt of Reparation payments from Germany) and to enable the French to amass balances which were left within call in other countries. The funds that accumulated in this country were largely French funds.

In the second place, as we have already seen, a large proportion of the savings of the people of different countries, instead of being invested in long-term securities, were held within call. Thus a vast amount of capital (estimated at two thousand million pounds), which should, and normally would, have been invested in industrial and other long-term securities, was held in liquid form and was moved about in search of security—security which included rapid realisability and was of more importance than a substantial difference in the rate of interest. That confidence which is generated by peace and normal economic development was lacking; the risk factor was overvalued. One result was that industries became heavily burdened with fixed-interest and short-term debts. In this connection it is important for the future to observe that the distinction between investment capital and what I have called liquid capital has lost much of its importance. The war has resulted in a large increase in securities (mainly issued by governments) which can be realised upon an international market with very little delay. These securities are now held to a greater extent than in the past by people who

wish to retain their capital within call. They are therefore far more susceptible to sudden changes in demand and immediately available supply, and their existence on such a large scale has added to the instability of the post-war economic world.

In the third place, a change of the first importance has taken place in the financial relationships of nations without a corresponding change in their industrial structures. The United States of America provides the outstanding but by no means the only example of such change. Immediately before the war that country, although a heavy debtor, had ceased or almost ceased to be, on balance, a borrower. Her industrial structure was appropriate to that state of affairs. She possessed a large export surplus representing interest upon, and to some extent the repayment of, the accumulated loans of the past. The war enabled her not merely to pay off her debts but also to become an important creditor state. Her industrial structure remained practically the same as before; the interest element was transferred from one side to the other side of her account with the rest of the world. Not only did she possess an export surplus in respect of commodities and personal services but that surplus was now augmented (where once it was offset) by interest payments. She was like Mr. Manhattan of comic opera fame, "all dressed up and no place to go." One factor in the situation is the amount owing to America in respect of so-called war debts, but from her point of view it is not an important factor. The much discussed transfer problem is as relevant to and important for America in the case of other forms of indebtedness as in that of the debts of other governments. What is peculiar to the so-called war debts is the fact that they represent a contract between two governments, but this is of no international economic significance.

The failure to fit the industrial structure of the world to the new financial relationships between nations constituted one of the real difficulties in operating the post-war standard. I have already referred to the fact that, before the war, gold moved from one country to another in response to economic influences and that such movement produced its effect upon monetary policy and relative price levels. Since the war the changed financial relationships have caused not merely a large-scale movement of gold but also a concentration of gold in those countries in which the change in financial relationships, with the given industrial structure, had not been fully offset by a policy of foreign investment. Thus France and America have jointly amassed a large proportion of the total world supply. But they have not allowed that supply to produce its pre-war effects. About ten years ago Mr. McKenna rightly pointed out that America was on a dollar standard, not the gold standard. It is, I believe, literally true to say that at no time since 1920 has the United States been on the gold standard in the full technical sense of the words. It is equally true to say that France, while legally on the gold standard since 1928, has never accepted the implications of that standard. The reason for the failure of these two countries to employ the gold standard in the full sense of the words is to be found in their unwillingness either to adapt their industrial structures to the new finanical relationship or to

embark upon such a policy of foreign investment as would enable them to maintain the existing industrial structure.

Again, the credit system of the world has been completely disorganised. The change in the relative financial strengths of Great Britain, America and other countries, has tended to reduce the pre-eminence of London as the financial centre of the world ; the power of the City has been challenged by New York and Paris. But that is not the only change that has occurred. I have already referred to the existence of a large mass of liquid capital that would normally have been absorbed by industry in the form of long-term investments. This liquid capital has not been employed by the Central Banks as a stabilising factor ; on the contrary, it has proved to be a disturbing factor. Before the war the Bank of England, as the centre or controller of international credit, employed such credit in the service of distressed countries and thereby maintained financial stability. Since the war it has not been able to perform this function with the same effect, while other countries that were able to render assistance could not be relied upon. When the credit of any country was threatened, foreigners withdrew their funds in search of security. When, in 1931, we needed the type of assistance that we were accustomed to render to other countries, the latter deserted us like rats deserting a sinking ship. A large mass of liquid capital moved about the world leaving crisis in its train and creating embarrassment to the countries that it sought, always hunting for security without ever being sure of finding it. The most recent victim of the damage wrought by this movement is the United States of America.

V.

In the fourth section of my paper I have tried to indicate those differences between the pre-war and the post-war gold standards which accounted for the success of the former and the failure of the latter. The question arises whether, under present conditions, it is worth while either to restore the gold standard or to establish any other form of international metallic standard. It is known to all economists that the difficulties of working the post-war gold standard were increased by technical defects in banking organisation, particularly in the United States of America and in France. A discussion of these defects would not be possible in this paper ; I refer to them merely to indicate that I am aware of their existence. But I believe, and I therefore assume, that if the more fundamental difficulties to which I have referred were overcome it would be possible to solve purely technical problems.

The essential feature of the gold standard is that it maintains a fixed rate of exchange, establishes an international price system in the sense of a common measure of value, and controls the internal or domestic supply of currency and therefore the domestic level of prices. It seems to me that if we are to return to the gold standard it must be a standard that retains this feature. Before the war a movement of gold from one country to another automatically reacted upon the relative supplies of money in the countries affected. It has been suggested by the Gold

Delegation appointed by the Economic Section of the League of Nations that in future the various countries should maintain free reserves of gold. The gold supply of a country should be divided into two parts, the first being the legal reserve against currency, the second being the surplus available for export. The purpose of the scheme is to secure that an export of gold from or an import of gold into the reserve should not react upon the currency policy of the country concerned.

It seems to me that this proposal would destroy the vital element in the gold standard. In recent years we have seen how free reserves are actually employed in practice. In America they were placed on the most inaccessible shelves of the vaults of the Central Banks. In many of the smaller countries they were virtually added to the legal reserves. They were exported with extreme reluctance and the loss of gold even from those reserves reacted upon the discount and currency policies of the losers. Further, it is clear that if all countries maintained free reserves, a considerable proportion of the total reserve of gold in the world would be rendered ineffective as a foundation for currency, with the result that the gold price level would be lower than under the alternative system. But the real argument against the proposed system is that a movement of gold would not be producing the effect upon internal policy that such a movement ought to produce under normal conditions. At best we should be using the cumbrous method of moving actual gold instead of the pre-war method of moving liquid capital or providing credit ; at the worst it would delay a domestic adjustment so long as to make such adjustment greater and more difficult and thus endanger the standard itself. For these reasons it seems to me that the proposal does not constitute an improvement upon the pre-war gold standard. The same reasons lead me to believe that the suggested compromise of establishing and maintaining a wide margin between the buying and selling prices of gold would destroy what is most valuable in the gold standard.

If we ignore other metallic systems it seems to me that the real issue lies between the gold standard, rigorously interpreted, and the maintenance of national currencies which are not linked together by being linked to gold or to any other common measure. When we abandoned the gold standard the alternative achieved considerable popularity in this country, but all recent experience has shown that, during a period of currency disturbance, it tends to increase rather than reduce our difficulties. My objection to the system, however, is due not to the fact that it has created or intensified difficulties under present conditions, but to the fact that it would create difficulties of the present type even though it were introduced under the best possible conditions. The system has been advocated on the ground that it would enable us or any other nation to pursue a currency policy that would maintain a stable price level. For reasons which I cannot give in this paper I believe that precisely that sort of stability which they seek is more likely to be achieved under the gold standard than under a system in which such stability is the immediate object of national policy. But it seems to me that a wider and deeper issue than even price stability is involved in the discussion of the two alternative monetary systems. The national

currency system is but one aspect of economic nationalism or economic isolation, of which tariffs is another. A national system of currency is intelligible if not defensible for a nation which isolates itself from the family of nations. It is not, however, consistent with a policy of internationalism in other departments of economic activity. The gold standard stands for internationalism in economic affairs ; it is a condition of free development of trade between nations. Nor should it be forgotten that, if most countries were on the gold standard, secular changes in the value of gold would be relatively small. Post-war changes in the value of gold have been due not to the gold standard but to the failure of a number of countries to operate that standard.

Without pausing to consider the case for bimetallism, I venture to express the belief that the restoration of the gold standard is necessary to the progress of the world in that future which is worth considering. I am content to leave the twenty-first century to our great-grandchildren. I do not, however, suggest that the gold standard should be immediately restored ; on the contrary, I fear that political considerations will drive us back to that standard before the essential preliminaries have been properly considered. In the first place, it would be folly on our part to return to gold until we knew precisely the rate of exchange that would enable international trade to be distributed in the manner determined by real costs of production. The new rates should be determined by purchasing power parities. We are not yet agreed, however, upon the precise meaning of purchasing power parity, neither do we possess the information that would enable us to estimate purchasing power parity, howsoever defined. Again, we should not return to gold until the price averages of different countries, expressed in their respective currencies, have reached those heights which are regarded as satisfactory ; for it is clear that subsequent changes must be international rather than purely domestic in character. Further, we should not restore the gold standard until individual countries are prepared to pursue investment policies that are appropriate to the remaining parts of their economic structures. It is too much to hope that the great mass of liquid capital which now readily—too readily—flows from one country to another will quickly be invested in long-term securities and thereby cease to be a danger to the financial stability of a number of countries, but it should be easy to form an international exchange stabilisation fund under the control of an appropriate body which, in effect, would perform the pre-war international function of the Bank of England. Such a body would direct the flow of funds according to the needs of individual countries, not, as at present, in the opposite direction.

A word should be added on the question of tariffs. Before the war the tariff system of each country was determined by long-term considerations. During the last few years all countries (our own included) have found refuge in the doctrines of the mercantilists of earlier days. Tariffs have been used not to direct the development of industry but to direct the immediate flow of trade. An adverse balance of trade is no longer regarded as an incident of economic growth but as a calamity to be avoided at all costs. An established system of protection is not inconsistent

with the operation of the gold standard, but frequent tariff manipulation to meet fluctuating trade balances is bound to render any international currency standard impossible. It is too much to hope that the world will abandon tariffs as a measure of protection, but it will be difficult to maintain the gold standard unless the countries of the world are prepared to abandon the system of *ad hoc* trade restrictions to overcome occasional deficits on current accounts. I do not believe, however, that I am too optimistic in stating that this difficulty would quickly disappear. The new practice of adjusting tariffs to failures to balance payments is largely the product of the failure of our credit system. If liquid capital had gone to the rescue of, instead of running away from, countries with adverse balances the need for dealing with the situation in another way would not have arisen. I therefore believe that if we could solve the problem of controlling the flow of credit, either through the creation of an international exchange stabilisation fund, or in some other way, the difficulties created by the new restrictions upon trade would also be solved.

We are frequently told that a return to the gold standard is impossible so long as the world supply of gold is so largely concentrated in two countries. It is no doubt true that the present distribution of gold presents a serious difficulty, but I do not regard it as an insuperable difficulty. The present distribution of gold is the result of those post-war influences to which I have already referred. If we could restore those conditions which are essential to the maintenance of the gold standard it is not unlikely that a redistribution of gold according to apparent need would be accepted. Gold is only preferred to an earning asset so long as the earnings of the latter do not exceed the money estimate of the risk involved. In the last resort, however, the international price level in terms of gold matters less than the domestic price levels expressed in local currencies, so that the difficulty created by an unequal distribution of gold could be overcome by giving an appropriate gold value to paper currency and maintaining a relatively low legal reserve. Moreover, if domestic price levels, expressed in local currencies, are sufficiently high, the burden of fixed debts necessitating a flow of payments from one country to another would not be so heavy as to endanger the gold standard. A recent judgment in this country, and still more recent pronouncements in the United States, have shown that debts contracted in gold are no longer payable in the gold value expressed in the bonds. A foreign debt payable 'in sterling in gold' in this country can be paid in sterling; a gold bond payable in gold dollars can be paid in dollars. This decision has produced a profound effect upon the significance of the gold price level in the world and, therefore, upon the present distribution of gold supplies. For these reasons, while admitting the importance of a change in the distribution of gold, I do not believe that the present distribution, or the probable distribution in the near future, constitutes an insuperable obstacle to the return to the gold standard.

I hope it will be evident that I neither contemplate nor desire an immediate return to the gold standard. Many changes must take place before such action can be taken with safety. When a new currency measure is

passed we shall be legislating not for a year but, we hope, for a generation or more. It should not be forgotten, however, that the gold standard is a form of discipline which may itself help to restore some of those conditions that enable it to be operated with success. It is a problem in the art of government to decide when the necessary changes have occurred, and how much may be left to the discipline of the standard itself. In deciding the actual gold value to be given to sterling, I hope that the post-war difficulties of the unsheltered industries will not be forgotten by the Treasury.

SECTION G.—ENGINEERING.

SOME EXPERIENCES IN MECHANICAL ENGINEERING

ADDRESS BY

RICHARD W. ALLEN, C.B.E.,

PRESIDENT OF THE SECTION.

The variety and range of subject-matter selected for the addresses of this Section reminds me how vast a field of human endeavour is now occupied by the engineer ; how manifold are the branches of his profession ; how diversified are the activities ; and with reflections such as these, I realised that I could not hope to range over the whole of the relatively limited though still vast field of mechanical engineering, though through a life of fifty years I came to the conclusion that for the purpose of this address ' Some Experiences in Mechanical Engineering ' may be a suitable subject.

While discussing the progress which has taken place it seems desirable to give some definition of what is meant by ' mechanical engineering.' The expression is often used loosely, and indeed it is not easy to sum up the scope of mechanical engineering in a few words. For electrical engineering activities are almost inseparably interwoven with those of the mechanical engineer ; and the same may be said of civil engineering. There is in truth no hard-and-fast dividing line between the various branches of the engineering profession ; no one point at which we may confidently say, ' Here mechanical engineering ends, and there some other form of engineering activity begins.' Nevertheless it is manifest that if engineering can best be defined as the adaptation of the forces of nature for the service of mankind, then, I suggest, mechanical engineering may be described as that branch which deals with invention, design, construction, and the installation and operation of machinery by means of which those forces are harnessed and applied.

By the extent to which natural resources are thus utilised one may measure—materially, if not morally—the degree of civilisation of a people. The story of the progress of civilisation, in the use of machinery, is a fascinating but a somewhat neglected study. Just as the accumulations of succeeding ages have buried the remains of early man, so the rapid succession of new inventions and the modifications of old ones have heaped up a quantity of material that tends to diminish our appreciation of the labours of the past. We are apt to take most things for granted, and to pay little heed to the efforts of those earlier workers by whose labours we profit—notably in the use of machines.

The history of discovery and invention constitutes, indeed, a relatively insignificant portion of 'history.' Too frequently does this consist almost exclusively of a recital of the political changes, the military achievements, and the rise and fall of nations and peoples, and of the men who have had brief authority over them. Men and even nations pass and are forgotten, but knowledge begets knowledge and cannot be stayed, continuing to expand at a rate which it seems that no past epoch can possibly rival, while it must be exceedingly doubtful whether the future will afford a parallel; but a time will assuredly come when the achievements of men and matters of the present day will be appraised at their full value.

It is, above all, an age of time-saving and labour-saving devices. If mechanical engineering is not to fail in its destiny, then its gift to mankind must be that of increased leisure. It must be admitted, however, that at present the 'load' is distributed very unevenly, nearly three millions of our people being unemployed, so that they must be carried on the shoulders of the rest. There can be no question that we are now moving so quickly that it often seems doubtful whether mankind can adapt itself to the rapidly changing conditions; and there is thus even a tendency to question the advantage of science, and the value of progress, as factors in human happiness. It is as if conservative and unimaginative humanity, caught up by a sea of advancing and fast-accumulating knowledge, sorely buffeted by the waves it has created, is being carried into unknown waters, far from the lighthouses of past experience.

In mechanical engineering the last few decades have witnessed almost incredible advances. We who live in these amazing times cannot appreciate the rate of change, and can comprehend only imperfectly the vastness of the new era. One may recollect that Francis Bacon, whom Sir Richard Gregory has designated as the great apostle of modern scientific method, 'aspired to take all knowledge for his province.' It is a striking commentary upon the progress of science that engineering knowledge alone is now far beyond the scope of any one man, even though he were of the mental calibre of the great Lord Chancellor himself.

It may be useful to look back over the past fifty years and consider the changes which that period has effected in the field of mechanical engineering. Turning first to electric power plant, we may note that, fifty years ago, there were no steam turbines, no Diesel engines, no petrol engines—indeed, no internal combustion engines of any kind other than gas engines. Again, while the electrical generation, transmission and application of power were then practically unknown, it is estimated that the world's production of electrical energy to-day is of the order of 200,000 million units per annum. As recently as the year 1895 Lord Kelvin put forward the statement that he saw no reason why power stations of 100,000 h.p. under one roof should not be feasible in the future. This prediction, then regarded as a fantastic dream, has been abundantly fulfilled, for the development of this power in one turbo-generator is now accomplished; and here we may consider briefly the development of three very important contributions to mechanical science—namely, the steam turbine, the Diesel engine, and the centrifugal pump.

The development of the steam turbine has taken place entirely during

the last fifty years. It was the great pioneering labours of Sir Charles Parsons, however, which laid the main foundations for the turbine design of to-day. He saw the need for compounding his first turbine, of reaction type. This simple non-condensing turbine was naturally very uneconomical, and as a result the condensing turbine was conceived, whereupon turbine steam consumptions and costs began to approximate to those of the best reciprocating engines. In the early stages of turbine development considerable difficulty arose from the fact of this prime mover being more suitable for large outputs, for which in those times there was no demand. Parsons next initiated the application of the turbine to ship propulsion, building the s.s. *Turbinia*, in which the propellers were driven direct; the result being that, while the turbine speed was too low, that of the propellers was too high to give the best results.

In the meantime the experience gained on the *Turbinia* had resulted in the design and adoption of the geared turbine, which not only improved the position for the smaller sets on land, but also found the solution to the problem of marine propulsion—namely, a turbine running at a high speed and a propeller at a much lower one, thus producing a condition which gave maximum efficiency.

Progress on the marine side has been so rapid that units capable of developing 50,000 shaft h.p. have been constructed.

On land the progress has been no less rapid, and the application of the geared turbine has enabled continuous current dynamos to be built for capacities up to 3,000 kw. per machine. Further, the application of the geared turbine has been extended to operating various kinds of mills and to other fields where its greater economy of space and steam consumption give it advantages over the steam engine.

Recent developments in turbine design have tended to endorse the principle laid down by Carnot, that the temperature of heat supply should be separated as widely as possible from that of heat rejection. Thus, total temperatures are creeping upwards. Among other means of improving the efficiency is that of feed heating by means of steam tapped off from the turbine between the expansions.

There are many examples of large turbine plant approaching a thermal efficiency of 30 per cent. from fuel to electricity, and machines have been constructed giving, at the terminals, one kw.-hour for 10,000 B.Th.U., corresponding to a thermal efficiency of the turbine of more than 34 per cent. Although there are turbines at present in commission developing 200,000 kw., these very large machines, I understand, show little, if any, improvement in efficiency over a machine having an output of, say, 40,000 to 50,000 kw.; and it seems rather unlikely that the size of unit will tend to increase in the future.

The development of the oil engine is another feature of cardinal importance in recent engineering history. It was only forty-one years ago that Dr. Rudolf Diesel obtained his famous patent which was destined to effect a revolution in the design of an oil engine. It was the intention of the inventor to burn coal direct in the working cylinder, but this was found to be impracticable, owing to the large quantities of unburnt residue. He thereupon turned to the possibilities of oil, and, after four

years of persevering experiment, the first practical engine was constructed. It may be that a satisfactory internal combustion engine, utilising powdered coal as fuel, will be one of the developments of the future ; but so far oil has proved to be the only fuel capable of satisfactory employment in engines of the Diesel type.

We may consider for a moment the conditions under which the fuel was to be burnt in the working cylinder, conditions which—whether the fuel be in colloidal or liquid form, and whether its injection be by high-pressure air or by mechanical means—are fundamentally the same to-day. The Diesel cycle relies, for the ignition of the fuel delivered to the cylinder during the working stroke, upon the temperature resulting from the high-compression pressure to which the charge of air is submitted, a pressure of some 500 lb. per sq. in. Ignition begins at about top dead centre, and continues for a definite part of the power stroke. The burning of the charge takes place at roughly constant pressure, the process being sometimes designated as the ' slow combustion ' or ' constant pressure ' cycle. In comparison with other available types of prime mover, the earliest practical Diesel engines were thermally very efficient, and this, together with the manifold advantages of oil for fuel, has led to an increasing exploitation of the oil engine down to the present day.

The advantages of the Diesel engine for ship propulsion—resulting in a decided economy as regards fuel, space, weight—were recognised early in the present century. A milestone in the history of technical development is denoted by the launching of the *Selandia* twenty-three years ago, a vessel 370 ft. long, fitted with a four-cycle engine. It is interesting to record that this ship is still in service and very successful results are still being obtained. During the last twenty years considerable developments in the building of marine Diesel engines have taken place.

The supply of high-pressure air for fuel injection purposes has always been a difficult problem. With normal designs, a pressure of at least 1,000 lb. per sq. in. must be available, while the compressors must keep in tune for long periods of service, involving a considerable maintenance charge for suction and delivery valves, cooling coils and compressor pistons. Again, several years before Diesel's patent, Ackroyd Stuart had made use of mechanical injection on a low-compression engine, but, in spite of the various advantages of this system of injection, there was for a long time no serious attempt to apply it to the Diesel engine. Not only does the employment of mechanical injection remove the disadvantages associated with high-pressure air, but dispensing with the compressor drive from the crankshaft improves engine balance, reduces the overall length and weight of the power unit, and increases the overall thermal efficiency of the engine. A notable feature of the mechanical injection engine is the ability of the governor to take sole charge of the engine throughout the entire power *and speed* range, without the necessary complications by having the blast air supply under control when running under a varying speed range.'

More recent developments in engines operating on both the ' constant pressure ' and ' mixed pressure ' cycles have led to gradual but persistent reductions in the weight and size of the components, thus enabling speeds

to be raised and the power output per unit of weight greatly increased. At the present day engines are made of a vast number of different types, two- and four-cycle, single- and double-acting, vertical and horizontal, each meeting a particular set of conditions in service. Starting by compressed air is still the most usual method, being universal in the case of large engines. For traction purposes, however, and for the smaller stationary sets, electrical and mechanical methods now receive increasing attention.

There is boundless scope for the application of the Diesel engine, both actual and potential. Its low initial cost, the limited space required for its installation, the ease of starting from cold, and its low costs of operation and maintenance, are all contributory to its great industrial exploitation, particularly for such public services as water and electricity supply, sewage and drainage, apart from industrial application. For marine purposes the Diesel engine is making steady progress in its adoption for the main propelling machinery. With its convenience and reliability for auxiliary purposes it is so widely appreciated as to require only passing mention here. Examples of this type of plant are to be seen in many modern passenger ships. The recent development of a high-speed engine, combined with small size and low specific weight, make this engine particularly suitable in railway work for locomotives, where low operating costs and low standby losses are essential. This is a sphere into which the Diesel engine in our country has only recently entered, but its singular suitability for this type of service encourages one to expect rapid strides to be made in this direction. So far as industrial road vehicles are concerned, this type of oil engine has come to stay, while its resiliency of running has permitted its installation in crowded residential areas—even in the basements of steel structures consisting of flats, where freedom from noise and vibration are imperative. There seems, indeed, to be no limit to the sphere of utility—of necessity, even—for this prime mover.

The centrifugal pump is also largely a development of the period under review. As is frequently the case, the principle was known long before it was applied successfully to practical uses. There is evidence that Leonardo da Vinci, the great artist, engineer and inventor, realised the possibility of utilising centrifugal force for raising water, though the invention of the centrifugal pump is usually attributed to Johann Jordan.

So far as known records go, centrifugal pumps began to be used for industrial purposes in the second decade of last century ; but at the time of the Great Exhibition in 1851 they were still regarded as a mysterious novelty. One shown by Appold at this exhibition created much interest because its impellers would pass an orange, this being one of the first steps in an important modern application of this pump, that of dealing with solid materials. For a long time the centrifugal pump could not compete with that of the plunger type for the greater pressures and heads, its efficiency falling off rapidly in the higher ranges, so that its use was confined chiefly to low lifts. When Osborne Reynolds's patent was disclosed in 1875 the multi-stage turbine centrifugal pump appeared, and the use of guide vanes was found greatly to improve the hydraulic

efficiency at heads which had hitherto been thought quite outside the range of this pump.

In the pioneer days of centrifugal pump development, when the method of calculation for design was somewhat rudimentary, a number of basic facts were discovered experimentally, from which empirical relationships were devised to meet the various conditions imposed. Later on, the advances made in the design of high-speed prime movers, particularly of steam engines and electric motors, gained for this type of pump a pre-eminence which it has maintained ever since and seems likely to enjoy for some time to come. To-day, although we have still much to learn, centrifugal pump design has become a highly specialised study, and characteristics can be forecast, for numerous combinations of conditions, with a reasonable degree of accuracy. Compared with the plunger type, the centrifugal pump has the advantages of much lower capital and maintenance cost, with concomitant economy in space and weight, which renders it particularly suitable for use on board ship. It can be run in special cases with a shut-off head. It has a reasonable measure of unchokeability, while its delivery at constant pressure makes it peculiarly applicable to boiler feed and similar duties.

A striking application of this pump has been in the handling of coal, sands, gravels, and the like, where, in spite of the abrasive nature of the materials, maintenance costs can be kept comparatively low, while lined pumps of special construction are capable of passing stones and boulders up to the size of the delivery branch.

The much improved efficiency now obtainable from centrifugal turbo-pumps has led to a marked increase in their use for waterworks installations, where the high speed enables large quantities of water to be delivered from a comparatively small bore-hole. The pump is suspended, often many hundred feet below the surface, from a rising main, the impellers being driven by vertical shafting supported in bearings fitted to the rising main itself, or, occasionally, by an electric motor which runs submerged.

A comparatively recent development is the axial-flow type of pump, and this, with its advantages of reduced weight and space, and higher speed, may—when dealing with low heads—be said to carry the low cost of construction and installation a stage further. Because the flow is unidirectional, the pump being merely an incident in the pipe, higher speeds can be obtained with lighter prime movers. Intermediate types, partly centrifugal and partly axial-flow, have also been devised. While no one dare prophesy as to the future of the pump, it would appear that both centrifugal and axial-flow types are in essence so simple that it is difficult to see how any future improvement can be expected, except in detail.

These technical developments have amazingly increased the field of application of the centrifugal pump, particularly for graving and floating docks, impounding for wet docks, and in the drainage of watery wastes and the irrigation of barren deserts, so as to bring large areas of ground previously unproductive into a state of high fertility—often affording, indeed, a sure means of subsistence to peoples whose very existence had hitherto been precarious. In our own country, before the beginning of

the present century, only a comparatively small area of the fenland had been drained, and then almost entirely by antique methods, as by scoop wheels driven by windmills or beam engines, whose efficiency was in inverse ratio to their æsthetic value. Here the development of modern steam and oil engine-driven centrifugal pumps has supplied a considerable impetus to reclamation. In China and Japan great areas of waste land have similarly been drained and brought into cultivation.

The economic advantages of irrigation work in Egypt and the Sudan are familiar to many. In Egypt during the last fifty years the developments are very remarkable for their size and number of installations. Only after a visit to that country can one fully appreciate the vastness of the enterprise and the work carried out there by the engineer. In the Sudan, irrigation schemes date from the Battle of Omdurman, when the power of the Mahdi was broken by Lord Kitchener, and the tribes of the Sudan, whose previous occupation had been largely that of war, had somehow or other to maintain themselves in a country ill supplied by nature with the means of peaceful existence. The suggestion that cotton could be successfully grown in the Sudan, followed by the construction of experimental pumping stations—even so far afield as Fashoda—was crowned with success, leading to the foundation of the Gezira Irrigation Scheme and to the formation of the Sudan Plantations Syndicate, so that to-day the Sudan furnishes a considerable proportion of the world's supply of this commodity, and of the highest quality. In many other countries, as Australia, New Zealand and elsewhere, irrigation methods only possible by the installation of modern pumping plant have resulted—as, for example, at Mildura—in the development of Australia's great fruit-growing industries.

Another field in which production has been greatly increased by mechanical methods is the tin industry of the Federated Malay States. The antiquated Chinese method of raising water from mines by means of hand buckets, sometimes in one or two up to as many as six stages, was slow, laborious and costly, as compared with the use of a centrifugal pump of modern type. Again, the method of hydraulicing—where a jet of high-pressure water is directed against a hillside, so as to wash it completely away for treatment—has provided still further scope for the use of centrifugal pumping plant.

Shipbuilding has always been one of our national industries in which we Britishers take a legitimate pride—an industry in which we are leaders throughout the world. Wherever the British flag flies, in the Navy or the Mercantile Marine, graving or floating docks are to be found. To the engineer the design and construction of such docks present problems of absorbing interest—problems ever new, since the conditions to be faced differ widely between one country and another, requiring special treatment to suit the local surroundings.

To deal adequately with the pumping machinery required for graving and floating docks both at home and abroad would take too long, but nevertheless it is a subject which has always appealed to me as one not only fascinating but full of romance.

A survey of recent mechanical progress, though only in outline, would

be incomplete without reference to the various classes of machinery used for purposes of production. Nevertheless the changes which have taken place in recent years are so extensive that they can only be indicated here in general terms. It would be difficult, without reference to illustrations in the records of the time, or to actual exhibits such as those in the Science Museum at South Kensington, to convey to the younger generation of engineers how elementary was most of the industrial machinery of 1883 compared with that of to-day—how relatively limited in quantity, capacity and range. Yet already the seeds of change had been sown. For several decades British ideals in machine construction had been in conflict with those which had found their way to this country from abroad. British engineers were accustomed to an ample factor of safety, massive design, slow-speed operation, and a regard for appearance. On the other hand, engineers in foreign countries were undoubtedly more ready to experiment freely with novel designs, and were responsible for introducing into this country what was then known as the 'manufacturing principle,' whereby large numbers of standardised articles were produced by repetition processes, with the aid of special-purpose machines designed for a single operation, thus reducing the necessity for skilled labour. As far back as 1854[1] it is recorded that Joseph Whitworth visited the United States and reported favourably on machinery for repetition work. In devising machinery of this kind, he reported, 'the Americans showed an amount of ingenuity, combined with undaunted energy, which we would do well to emulate if we meant to hold our present position in the great markets of the world.' About the same time James Nasmyth had visited the Colt pistol factory, then newly established in England,[2] and confessed that he had felt humiliated by the experience. He remarked further that 'The acquaintance with correct principles has been carried out in a fearless and masterly manner, and they have been pushed to their fullest extent; and the result is the attainment of perfection such as I have never seen before.'[3] But though British engineers of outstanding ability thus gave generous recognition to the lessons which were to be learnt from abroad, there was—as Nasmyth himself pointed out—'a degree of timidity resulting from traditional notions, and attachment to old systems'; and this conservatism, no doubt reinforced by relatively lower labour costs, still held back the thoroughgoing mechanisation of British industry fifty years ago, and indeed for long afterwards. But in the end, with our well-known genius for compromise, we have succeeded in combining the best features of both types, with the result that British machinery still maintains its high prestige in the markets of the world. It is noteworthy too that other countries have not hesitated to benefit by the high traditions of design and workmanship which have always been upheld by British engineers.

But though the adoption wherever possible of repetition methods, involving standardisation and interchangeability of parts, had a marked

[1] New York Industrial Exhibition: Special Reports of Mr. George Wallis and Mr. Joseph Whitworth, *Parliamentary Papers*, 1854, vol. xxxvi.

[2] Colt's factory established in England, 1851.

[3] Select Committee on Small-Arms, *Parliamentary Papers*, 1854, vol. xviii.

influence on mechanical engineering progress, there was another influence which was destined to bring about revolutionary changes in the design and construction of machinery, in this country and, indeed, the world over. This was the gradual substitution of science, and the scientific method, for the 'rule-of-thumb' procedure of the so-called 'practical man.' The change in this regard has taken place almost entirely during the past fifty years.

As Sir Alfred Ewing pointed out in his Presidential Address to this section a few years ago, there were in 1881 a few great leaders—a Kelvin or a Hopkinson—who possessed the right kind of basic understanding, who could turn to theory for guidance and had the engineer's instinct to give it application. But most of the zealous workers of those days were groping in what was at best a half light, full of enterprise and enthusiasm and not much more. But the few great mentors to whom Sir Alfred Ewing referred were the pioneers who helped to bring about what I believe to have been a great material revolution in human affairs. For it was they, together with other leaders in the universities and elsewhere, who laboured at the development of engineering theory, and who first taught us to realise the illimitable benefits to be secured by the application of physical science to the whole range of engineering activity. When I look back over the period now under review I realise that the greatest lesson conveyed is that the advancement of engineering is in the last resort determined by the advancement of physical science. I would, indeed, go further, and say that my experience, specialised though it has been, has taught me that the whole structure of modern civilisation rests upon the progressive application of physical science to the ever expanding requirements of mankind.

During the past half-century there has been a similarly phenomenal development in many other branches of mechanical engineering, notably those concerned with the naval and military services, radio-communication, aviation, transport (including rail and road), etc. etc. Considerations of time make it impossible to deal adequately with these developments here, but, as we have already seen, it seems certain that at no previous time in the history of the world has mechanical development been so rapid.

While the history of engineering development is a fascinating subject, we have to live in the present, at a time when economic considerations have become of vital importance in their bearing upon technical matters, so that no apology should be necessary for discussing very briefly the scientific methods of carrying out an engineering installation of to-day.

Years ago any engineering firm of repute could obtain a considerable proportion of its work with no particular effort, sometimes even without the necessity of preparing a contract. Such times have gone by. There is severe competition for what seems often a somewhat limited amount of work, and sustained and intensive effort is necessary to secure the amount of business requisite to keep open one's works. The soil must be tilled diligently—sometimes, indeed, for years—before the crop is reaped. To achieve this end no effort must be spared. A prospective customer often requires much education as to the savings which will accrue from the substitution of new and modern plant for his obsolete machinery, and to

appreciate fully the varying considerations of first cost, running expenses, maintenance charges, and the like. Where, as with Government departments or municipal authorities, the scheme has often been developed to a considerable extent before tenders are called for, less preliminary work by a firm is required. The difficulties of preparing an estimate are not always fully appreciated, for changes in the costs of labour and materials must be envisaged, while urgent work will require the working of overtime, at higher rates. Consideration must be given to the financial standing of the customer, the necessary safeguards for both parties must be provided, and, in recent years, where foreign customers are concerned, the fluctuating rates of exchange have created further problems with corresponding anxieties.

In the engineering of a large installation it is not always possible for those at the head of affairs to attend to more than the general scheme. An engineer of suitable experience is consequently deputed to conduct the whole contract in all its branches, and he will call upon the technical experts attached to the various departments concerned. A document, referred to as a technical order sheet, is issued containing a concise synopsis of the client's specification, all special requirements and relevant matter concerning duties, speeds, consumptions of the various units comprising the whole installation. This document must further contain all information necessary for the various departments of offices and works. Accurate detailed records must be kept of all expenditure incurred in the construction and installation of the machinery. This can best be done by assigning to each section of the work a letter to indicate the class of machinery, and a series of numbers to denote the individual items. These identification marks will be stamped on each of the parts and will appear finally upon the finished article, thus facilitating the ordering of spare parts at a later date. Against these numbers, the draughtsman will book his time, the foreman will draw his materials from the stores, and the workman will fill up his time sheets. The cost office will then have no difficulty in ascertaining the expenditure at any stage of a contract, and will ultimately arrive at the total cost in full detail, for guidance in future estimates.

The question of housing the machinery has also to be considered, and if new plant has to be erected and operated beside existing plant which must meanwhile be kept running, difficulties may arise, the overcoming of which may call for ingenuity and resource of a high order. The preparation of drawings is the most important step in the earlier stages of a contract, and success will depend very largely upon the amount of thought and time that has been given to the work in the design and drawing office. As in the case of correspondence, so also with the drawing office, one leading draughtsman must be in charge of the whole of the work, so that the various sections of the scheme may be in harmonious relation with each other. Having obtained all the necessary technical details from the design office, the leading draughtsman will prepare a preliminary lay-out of the scheme, and this is critically examined, in conjunction with the customer, to settle any new points which may then have arisen. When all has been suitably arranged, a general arrangement

drawing is prepared, followed by detail drawings of the larger parts, which are issued to the pattern shop and forge, while foundation drawings are sent to the customer, so that the buildings can be constructed or adapted. Drawings of all remaining details and pipework will follow, complete with lists of material and any special drawings for erection on site.

An important section of the works manager's organisation is the planning department. This department will interest itself in preparing a programme of dates by which the different items must be complete in pattern shop, foundry, smiths' shop, machine shop, erecting shop, etc., so that the promised delivery date will be adhered to. This also involves a programme of work for the larger machine tools extending possibly six months ahead, specifying the hours allowed for the different operations.

The quality of the materials is the concern of the works laboratory, which must ensure that all material specifications are complied with, and, where the customer's inspector desires to witness tests, must arrange for these to be carried out without the causation of delay in delivering the material in question to the machine shops. In addition to such routine testing, the laboratory should carry out considerable investigatory work, to keep up with the ever-increasing demands of the designer and for the improvement of materials generally. Those parts of the machinery required to withstand pressure must be subjected to hydraulic tests some 50 to 100 per cent. in excess of the maximum anticipated.

Where possible, running tests are made at the firm's works under conditions approximating to those on site. A Diesel engine and dynamo set should be tested separately, the engine by the dynamometer brake method, and the dynamo electrically ; and a combined test may finally be run in the presence of the purchaser. The testing of steam turbines usually presents greater difficulties by reason of the great variation in conditions, but enough data must be thus accumulated on which to base a judgment of performance. Pump testing has also its complications, for a mine pump may deliver a small quantity of water against a head of 3,000 ft., while a graving dock pump may be required to handle a large quantity against a head of less than 50 ft.

Transport of the finished machinery to site must be considered from the efficiency point of view by rail, road, water, or air, the last named from necessity rather than efficiency.

In concluding this part of the address which refers to engineering works of various kinds, I have endeavoured to show the changing circumstances in which we live to-day and the difficulties which we have to face, requiring constant research and experiment. I would here like to pay my tribute to the Director, Sir Joseph Petavel, and his staff at the National Physical Laboratory, and express my gratitude for the help they have so readily given. It is my experience, and I recommend it to others, that when one is faced with a difficult problem the staff at the National Physical Laboratory is always ready to offer advice. I have not forgotten the recent meeting held at the Royal Society, under the chairmanship of Sir Richard Glazebrook, when a discussion took place on the suggestions for research work required for the advancement in engineering.

Further, all engineers owe a debt to the British Standards Institution, a very live body under the able directorship of Mr. LeMaistre, which has secured for our country a leadership in standards. Much time is now saved by the adoption of the various standards recommended by the Institution.

Here also I must refer to the invaluable services rendered by the technical Press of this country—of which those old-established journals, *The Engineer* and *Engineering*, are outstanding examples and representative of all that is best in modern journalism. It may be safely asserted that no news service throughout the world is actuated by higher principles, has a greater regard for accuracy, or shows a more steadfast sense of responsibility than that provided by our technical journals. The result is a trustworthy and highly educational record of engineering progress, illustrated by admirably selected examples of recent practice and developments both at home and abroad. To the leading articles in these journals most of us have long been accustomed to turn for helpful and stimulating comment upon matters of current interest.

Having dealt very briefly with a few reflections and given examples of modern engineering, this cannot be regarded as a complete story without a few remarks on the subject of the human side of engineering.

I have frequently been asked the question by many professors in engineering, ' What kind of work do you give our students to do ? ' That is a natural question, and the answer is largely dependent on the young engineer's outlook after he has served his pupilage.

The system of training which I am interested in was started by my father over fifty years ago, established on a sound basis, and has proved remarkably successful. The scheme has been modified from time to time to keep pace with changing circumstances, especially post-war conditions.

It will be obvious that the industry cannot be carried on efficiently without a continuous supply of highly trained engineers and craftsmen, and the training of the engineer is the all-important question. All systems of workshop training should be available without payment of premium, and it is now general practice to pay wages to all students and apprentices. It is necessary to provide workshop training for three main classes of students. First, there is the student who wishes to become a professional engineer, capable of taking highly responsible positions on the administrative, executive, technical or commercial sides of the industry. There is, and there always will be, a considerable diversity of opinion as to the merits of different systems of training for the higher posts, and, since the characteristics and personality of the individual are varied, it becomes obvious that the course which is ideal for one is not necessarily best suited for another. In any case, a university training is desirable, as developing a disciplined mind and ensuring that thorough grounding in the fundamentals without which no engineer can be complete. An essentially Scottish system of training, which has proved very successful, is the ' sandwich system ' of winter in college and summer in the works. It is sometimes advocated that a student should undergo some years of works training before proceeding to the university. My own

experience leads me to believe that a university course, followed by works training, will be found generally most successful. Having completed the university portion of his training, it is not advisable for the student to decide upon the particular section of the industry in which he will engage, for, without a thorough working knowledge of the whole, neither he himself, nor those who have so far been responsible for his training, can possess sufficient data about his capabilities, or the particular branch of engineering for which he is most suited. Before this is decided it is essential that he should spend three years in some selected engineering works, passing from the pattern shop through the foundry to the forge, on to the machine and fitting and erecting shops, through the steam engine, oil engine, and electrical testing departments, and so on to the drawing and design offices. Interspersed among this portion of his training there will be various periods of erection work either at home or abroad. Some time in his third year of training he and his superiors can begin to form an opinion concerning the branch in which his particular abilities can be most fruitfully employed. He may be mathematically minded, in which case he would be most useful on the scientific and technical side. A man of strong practical bent would find ample scope for his talents in some such post as that of assistant to the works manager. Or his predilections and personal attributes may constitute him an ideal salesman; or he may have a desire to go abroad. In the training of the engineer this practical experience, obtained in all the main departments of a large works, must be regarded as a fundamental necessity, and he will obtain at the same time that contact with and understanding of his fellow-men which will give him a capacity for co-operation and leadership, indispensable for the professional engineer of to-day.

There is next the student who comes into the works from a public or secondary school, after reaching School Certificate or Higher School Certificate standard. He may ultimately attain to the same posts as are available to the university-trained student, but the road is harder, and only to be traversed by those possessed of enthusiasm and determination. Not only must he pursue a three or four years' course, passing through all the main departments, but he must also attend evening classes, so as to raise his education as nearly as possible to the standard of the university student. During his passage through the works he must become a student of one of the three institutions—Civil, Mechanical and Electrical Engineers—and, if his capabilities be wide enough, he should take an external university degree. Much hard and intensive work is entailed, and there are many who fall by the wayside, either from physical disability or flagging enthusiasm. But those who succeed, whose character impels them to overcome, by pains and tribulation, an initial handicap which can prove very hampering, are among the salt of the profession.

A further problem of industrial training is involved in the production of craftsmen, chiefly recruited from boys leaving an elementary school at the age of fourteen or fifteen, who, after a preliminary probationary period in the works, are apprenticed, at the age of sixteen years, to some particular branch of the trade. It is obvious that the general training of any such boy must continue in some way or other during the whole of his

apprenticeship, for only thus can he acquire the educational and technical equipment necessary for his duties and position. The way to the attainment of more responsible positions must not be barred even to these, who should not be allowed to pursue their way unencouraged by the hope of attaining a worth-while goal. Thus, while the boy, during his five years' apprenticeship, is attending evening classes and seeking to acquire knowledge in all possible ways by which to qualify himself for the pursuit of his trade, he should be able, by competitive examination in the works, to qualify for a ' student scholarship,' from which point he may advance to positions normally open only to those with university or equivalent training. The ' scholarship ladder ' from the elementary school to the university must have its equivalent ' apprenticeship ladder ' in the works, and it must be just as possible to-day for another George Stephenson to begin at the bottom of the social ladder and achieve the heights above.

The training of boys other than apprentices presents an even more difficult problem. Such boys may often be temporarily engaged in ' blind-alley ' occupations, and it is essential to provide for their transfer, at a sufficiently early period, into other channels which provide proper opportunities for advancement and the attainment of a satisfactory status. Any boy worth training should, of course, become an apprentice, when his training is automatically provided for.

Training, however, is not confined solely to the material and technical side. Although the passage of a student through any works may appear to be a severe and laboriously practical affair, it should at the same time engender a spirit very much akin to the Public School spirit, which is essential to the formation of a true engineering character. Amongst our own students at Bedford this spirit is fostered, even though past students may be scattered over the whole world, by the publication of an annual Works Magazine, and the formation of a Past and Present Students Association, which holds an annual reunion and dinner, maintaining contact which is so valuable.

One cannot leave this subject without paying a justly deserved tribute to the craftsman upon whom devolves the task of translating the ideas of others into practical shape. The production of work of the first quality necessitates the loyal and intelligent co-operation of all, and the quality of the finished article reflects the ability of every one of those responsible for its production. There must also be remembered those who are sent, often abroad, to bring the erection and completion of some engineering works to a successful issue. Such men must possess ability, character, and that quality of leadership which, difficult though it may be to define, is none the less real and essential. Circumstances may sometimes be those presenting unparalleled difficulties, but the fact that they are invariably overcome, and that other countries have on occasion employed British engineers to erect their work, affords striking confirmation that they stand pre-eminent in their craft.

I must here refer to the work of the Institution of Mechanical Engineers. The Institution was founded with the objects of promoting the theory and practice of the science in all its branches, to promote inventions useful to its members and the community, to afford opportunities for the

meeting and interchange of ideas, and the collection and publication of information concerning mechanical engineering in general. To the development of both the science and the art the Institution has made many notable contributions, and the advancement in status of the mechanical engineer of to-day is due very largely to its intensive and continued efforts.

The work of this body has been no less valuable in the matter of training. The successive stages of Studentship, Graduateship, Associate Membership and full membership of the Institution—combining an examination with the requisite practical experience for each grade—constitute a means of qualification for higher posts, and this course should be followed by every young student, whether or not he already possesses a university degree. To the student who does not, it affords an alternative qualification of the same merit. That the Institution has faithfully pursued the aim of giving the widest possible training and the amplest of opportunities to those young men whose education is not of university standard is patent from the fact that it provides, to the elementary school boy, a means of attaining further knowledge. Thus, by attending the evening classes of any recognised technical institute, and by dint of hard work, he can obtain National Certificates in Engineering subjects, exempting him from certain portions both of the Studentship and Associate Membership examinations. From this point his education and works training can proceed, side by side, until he is elected an Associate Member. The university engineering graduate, provided he possesses the requisite works experience, may be elected to the Associate Membership without further examination. It will be clear, therefore, that—largely by the efforts of the Institution—a complete scheme of organisation for training in mechanical engineering exists in this country, and that the way to advancement is in no way barred to the young student who has not had the advantage of a university training, so that an adequate supply of trained engineers should thus be assured.

It is widely recognised to-day that too intensively mechanised an existence has a somewhat soul-destroying tendency. Welfare work is designed to counteract this influence, and may be defined as a systematic and sustained effort to humanise industry. The efficient worker must enjoy both physical and mental health, must possess undistorted ambition, and must have a true conception of citizenship and his responsibility to all his fellow-men. The making of a community of such individuals is the aim of welfare work. The need for such work would be demonstrated, if it were not already self-evident, by the fact that the Industrial Welfare Society now numbers among its members most of the leading firms in the country. The Society is particularly fortunate in having for its President H.R.H. the Duke of York. All engineers who have the welfare of the industry at heart must be infinitely grateful to His Royal Highness for his leadership in this vital matter, not only for the interest he shows and the great amount of time which he devotes to visiting so many works, but for the many practical suggestions for the betterment of conditions which he has made. It is impossible to overestimate the importance of welfare work among young men, for they are the next generation of

engineering workers. The welfare supervisor is responsible for the mental and physical well-being, the work, the progress and the destiny of each individual, and he must endeavour to provide such amenities as will lead to the achievement of happiness and the making of good citizens. Many works now provide a Boys' Club, by which the natural desire of all boys for companionship may be fulfilled and a spirit of team work promoted. Indoor games of all kinds and reading and writing rooms should be provided. The club should be run entirely by the boys themselves, who thus learn the meaning of corporate life and individual responsibility. The need for physical training is now becoming much more widely recognised, and a gymnasium is thus an important adjunct. For the welfare of the employees generally there should be the library, and the 'recreation club,' possessing its own sports field, where the sporting instincts of all employees—embracing the vigours of football, cricket, hockey, tennis, etc.—may be catered for; while the sociable habits of the men are also fostered by the 'Men's Institute.' In the case of many firms much, indeed, is done, and very little is left undone, to improve the conditions of all employees, both within and outside the works, and such amenities cannot but result in a general widening of outlook and a greater happiness.

In conclusion: these, then, are a few of the thoughts that have occurred to me. Whatever their worth, they have at least this advantage—that they are the product, not of 'a cloistered seclusion, far from the heat and dust of life,' but are directly derived from personal contact with, and observation of, men and things. And this, after all, is the essence of the scientific method as I understand it—to learn as far as possible directly from observation and experiment rather than indirectly from books. I find this view upheld by one of the greatest of former Presidents of the British Association, the late Prof. T. H. Huxley, who said: 'The great benefit which a scientific education bestows, whether as training or as knowledge, is dependent upon the extent to which the mind of the student is brought into immediate contact with facts—upon the degree to which he learns the habit of appealing directly to Nature, and of acquiring through his senses concrete images of those properties of things which are, and always will be, but approximately expressed in human language.'

SECTION H.—ANTHROPOLOGY.

WHAT IS TRADITION?

ADDRESS BY

THE RT. HON. LORD RAGLAN,

PRESIDENT OF THE SECTION.

A DICTIONARY definition of tradition is 'anything that is handed down 'orally from age to age'; that definition I propose to adopt, and shall begin by considering what it is that is handed down orally from age to age. Tradition then consists of—

(1) Methods of farming. Traditional methods are in most places followed in breeding, feeding, milking and killing animals; in ploughing, manuring and sowing the land, and in harvesting and storing the crops.
(2) Methods of craftsmanship. Houses are built; weapons, tools, implements, utensils, clothes and ornaments are made, in most cases, by traditional methods.
(3) Methods of eating, drinking, and preparing food.
(4) Methods of dealing with property. Even in civilised countries systems of land tenure, inheritance, and transfer of property are usually traditional.
(5) Marriage customs and ceremonies; bride-price, divorce, etc.
(6) Rites and ceremonies at birth, death and initiation.
(7) Etiquette. There are traditional ways of saluting, and of eating, dressing, and behaving in company.
(8) Superstitions.
(9) Games, sports, songs and dances.
(10) Traditional narratives.

Leaving aside for a moment the traditional narrative, we may then regard tradition as a code which, entirely in the case of the savage and very largely in the case of the civilised, regulates the conduct and activities of mankind throughout life. However much tradition may vary from group to group, it always has this in common, that it must be learnt in all its aspects by the younger members of the group, whatever the group may consist of, before the older members will admit them to the full privileges of membership. Whether a tradition is rational or irrational makes not the slightest difference; traditions about unlucky days or unlucky numbers are enforced as strictly as traditions of honesty and truthfulness. The traditions of our best schools and professions contain many absurdities, as do those of our courts of justice and of Parliament.

Tradition, then, is a code of rules, covering every aspect of human life,

which, though not taught by schoolmasters or enforced by the police, is handed down orally from the older to the younger members of the group, and enforced by public opinion within the group.

To this description there is one apparent exception, the traditional narrative, and to this I shall devote the remainder of this address. It must, however, be borne in mind that in any group the traditional narrative forms a mere fraction of the great body of tradition, of which some at least of the other forms are of far greater sociological importance.

The traditional narrative takes various forms, such as myth, legend, epic poem, ballad, saga and fairy tale. It has been usual in the past to divide these into two main classes, those which were believed to contain a kernel of genuine historical fact, and those which were regarded as purely fictitious. With fiction I shall deal later ; I shall now consider the claim of the traditional narrative to be the repository of historical fact.

The Basis of History.

The theory that traditional narrative embodies historical fact is based on the assumption that among the members of every community in which quasi-historical narratives are related there exists, and has existed for hundreds or thousands of years, a strong and continuous interest in the past history of the community, and a strong and continuous desire to preserve the facts of that history as accurately as possible. There appears to be no evidence to justify such an assumption.

Why should anyone wish to know what happened before he was born ? There is no obvious reason, and as a fact very few people do. All over the world we find people living in the neighbourhood of ancient ruins without taking the slightest interest in them. Historic monuments are being destroyed in England to-day, and by educated and responsible persons. If we wish to know who lived in a certain house a hundred years ago, it is of little use to ask the local inhabitants ; we may find some elder whose father worked there, but the odds are against it. Do we find, in any part of the world, young people sitting at the feet of the aged, and eagerly drinking in all that they can tell them of the events of their youth ? Nowhere that I have ever heard of ; the old man in his anecdotage is universally regarded as a bore.

Even when there is some slight interest in local history, it is the result of inquiries by students or tourists ; persons who study local history are called antiquaries, and they are rare in the most civilised countries.

As regards general history, he would be an optimist who would maintain that 1 per cent. of the inhabitants of Europe had any real knowledge of or interest in the subject. It is true that at times and places of high general culture there have often been a certain number of persons who studied history in the hope of understanding how people thought and acted under different social conditions, or of finding in the past the key to the future. It is also true that since the time of Herodotus many of the masterpieces of prose have been historical works, and that history has therefore tended to form part of the educational curriculum. None of these considerations, however, could affect the illiterate, who are interested in the present and the immediate future, but never in the past.

The only writer on tradition who has touched on this point, so far as I can learn, is Prof. Chadwick, who says: 'The existence of a poem 'or story which deals with reminiscences of tribal conflicts necessarily 'presupposes an absorbing interest in tribal history.'[1] He goes on to show that this interest could only be due to patriotism, but fails to realise that patriots are notoriously indifferent to facts; any fable which gratifies their national pride is history to them. The conclusion seems to be that since illiterate persons are never interested in history, historical facts can never be transmitted by illiterate persons.

In case, however, we may be thought to have gone too fast, let us ask another question: should illiterate persons wish to transmit historical facts from age to age, would they be able to do so? Let us first be clear as to what we mean by 'from age to age.' We do not speak of our parents' reminiscences as tradition, or apply the term to anything that happened within the memory of living men. We apply it only to events which may be supposed to have happened in the more or less remote past. We must also note that when a tradition is written down it ceases to be a tradition, and becomes merely the account of a tradition, unless we can be sure that those who repeat it have not been influenced by the written record. We may say then that a traditional narrative is one which has been handed down for at least a hundred years by people who have derived it from purely oral sources.

Let us now consider what are the sources of history. Apart from archæological evidence, which, however valuable, is seldom a guide to actual incidents, we may divide them into four classes:

(1) Accounts written at the time by persons who were present at the events which they describe—letters, despatches, memoranda, diaries.
(2) Accounts written by persons who were present, but not till some time afterwards—autobiographies, reminiscences, inscriptions.
(3) Accounts written by people who obtained their information from actors or spectators shortly after the event—annals, chronicles, proceedings of trials, newsletters, press reports, diplomatic correspondence. These would not be accepted as evidence in a court of law, but are often very properly accepted by the court of history.
(4) Accounts obtained by questioning people as to what happened a long time before, or accounts obtained at second or third hand. These are often recorded as survivors' tales, conversations, memories, gleanings.

Now it should be clear that the first three are, in varying degree, the only genuine sources of history. The fourth may be useful for reconciling discrepancies or filling in details, but would not be accepted as a satisfactory authority for a fact otherwise unknown. I know an old gentleman living not far from Leicester who has personal reminiscences of the French Revolution of 1848, but the fact would hardly be accepted on his sole authority. Second-hand evidence is not admitted in a court of law because it is notoriously unreliable. It is admitted by historians, but

[1] H. M. Chadwick, *The Heroic Age*, p. 273.

only if it is given by persons especially well placed or well qualified to obtain it. No one would accept a fact on fourth-hand evidence alone, yet this is what tradition is at best. Why historical facts should be capable of accurate oral transmission for hundreds and even thousands of years, while no other fact can pass down the length of a street without hopeless distortion, no one, so far as I can learn, has attempted to explain. Until someone has done so I shall feel justified in concluding not merely that no illiterate person has ever wished to transmit an historical fact, but that no illiterate person would be capable of transmitting an historical fact even if he wished to, and that M. Gaston Paris was right when he said that there was no such thing as historic oral tradition.

Tradition and Imagination.

At a later stage I shall give illustrations showing that incidents which occur in tradition are never historical, and, conversely, that historical facts never find their way into tradition. Here it will be convenient to deal with the belief that certain forms of the traditional narrative are the result of imagination, and then to set out my own view of the origin of the traditional narrative. The attempt to divide it into two classes, the historical and the imaginative, has been made by various writers, notably Hartland, MacCulloch and Krappe.[2]

Hartland tells us [3] that the art of story-telling is the outcome of an instinct implanted universally in the human mind, and that in the *Märchen* or fairy tale ' the reins are thrown upon the neck of the imagination.' MacCulloch says that all over the world simple stories were invented, and that ' as time went on and man's inventive and imaginative faculties ' developed, these simple stories . . . became incidents in longer tales.' [4] Krappe says that it is ' certainly excusable to take the common-sense view, ' and to regard the fairy tale as a definite type of popular fiction, primarily ' designed to please and to entertain.' [5]

Having stated it as an axiom that fairy tales are the product of the story-tellers' imagination, all three writers proceed, with a convenient inconsistency, to show that no story-teller ever displays any imagination whatever. It will perhaps suffice to quote Hartland. He says that ' it is ' by no means an uncommon thing for the rustic story-teller to be unable ' to explain episodes in any other way than Uncle Remus—" She wuz in ' de tale, en de tale I give you like hit were gun to me." ' After telling us that Gaelic stories often contain obsolete words ; that Swahili story-tellers hardly understand the sung parts of their stories, and that Eskimo story-tellers have to stick as closely as possible to the traditional version, he concludes that, wherever and whenever stories are told, ' the endeavour ' to render to the audience just that which the speaker has himself received ' from his predecessors is paramount.' [6] Then where does the imagination come in ? There is no more evidence that illiterate people invent fables than there is that they transmit historical facts. We must seek the origin of the traditional narrative elsewhere.

[2] E. S. Hartland, *The Science of Fairy Tales* ; J. A. MacCulloch, *The Childhood of Fiction* ; A. H. Krappe, *The Science of Folklore*.

[3] Pp. 1, 23. [4] P. 457. [5] P. 11. [6] Pp. 18, 21.

The Origin of the Traditional Narrative.

I said at the beginning of this address that all forms of tradition, with the apparent exception of the traditional narrative, were rules of conduct, and I do not believe that the traditional narrative is really an exception at all. In my view all traditional narratives are, or once were, rules—rules for the performance of rites or ritual dramas. Every rite or drama necessarily consists of a sequence of incidents, and the account of such rite or drama is therefore necessarily in narrative form. Unlike historical events, the interest of which can seldom be more than academic, the account of these rites *must* be preserved, because on their correct performance is believed to depend the prosperity of the community, and *can* be preserved because, unlike historical events, which occur but once, and usually in the presence of but few, these rites are performed repeatedly, and in the presence of all. Many of these rites and these narratives are world-wide, or nearly so, but variations occur, because there is always a tendency to tighten up the ritual in times of adversity and slack off in times of prosperity, and the narrative, being an account of what *has been* done rather than what *is* done, is usually a little different from the ritual. Finally, in many cases, the ritual ceases altogether to be performed, but the narrative has itself acquired sanctity, and may be passed on, necessarily with minor modifications, for many generations, until at last it is either written down or forgotten.

In my view this represents, in brief, the history of every genuine traditional narrative. I hope to make this view convincing by the performance of three tasks: the first is to show by illustration that there is no connection between tradition and history; the second is to show that the ritual drama has in fact played a large enough part in the life of mankind to account for the number and variety of the traditional narratives; the third is to show that the features of these narratives can be explained, and can only be explained satisfactorily, as features of the ritual drama. It will first, however, be as well to deal with two forms of pseudo-tradition, the 'family tradition' and the 'local tradition.'

'Family Tradition.'

There are in this country many families whose 'traditions' take them back to the time of the Norman Conquest, when their ancestors are alleged to have distinguished themselves either on the side of the Normans or of the Saxons. It can be said without fear of contradiction from those who have studied the subject that not one of these is a genuine tradition. All are the work of pedigree fakers, who have flourished from very early times, and there is not a word of truth in any of them. No English family can trace a genuine descent to the Saxons, and though there are a few families with a genuine Norman descent, this in no cases goes as far back as the eleventh century. Innumerable examples of these faked pedigrees and spurious traditions can be found in the works of Dr. Horace Round and Mr. Oswald Barron. Those who believe that a craving for historical accuracy is the ruling passion of the human race would no doubt suppose that all these families were very grateful to Dr. Round and

Mr. Barron for correcting their pedigrees, but they would be very much mistaken. I will give one example.

One of our oldest families is that of Wake, of which the present head is Sir Hereward Wake, thirteenth Baronet. The family 'tradition' is that it is descended in the direct male line from the famous Saxon hero, Hereward the Wake. The facts appear to be these. In 1166 a Norman called Hugh Wac came over from Normandy and married the heiress of the Norman FitzGilbert, lord of Bourne, in Lincolnshire. About two hundred years later the family of Wake, as it had then become, having attained to wealth and importance, thought itself entitled to a more high-sounding pedigree, and having discovered that a Saxon called Hereward had once owned a small part of the lordship of Bourne, decided to adopt the great Saxon hero as ancestor. For this purpose a pedigree was forged, conferring titles, ancestors and descendants upon the Hereward who lived at Bourne, and to make this pedigree more convincing there was conferred upon the Saxon hero the hitherto unheard-of cognomen of 'the Wake.' There are some obscurities in the story, but the following facts seem certain: that Hereward was never called 'the Wake' till he was adopted as ancestor by the Wake family about the middle of the fourteenth century; that the Wake family has no traceable connection with Hereward or any other Saxon; and that the first Wake to be christened Hereward was born in 1851. As regards Hereward the Saxon hero, he may have been a real person, but the fact that among his exploits are narrated the slaughter of a gigantic bear in Scotland, and the rescue of a Cornish princess, suggests that he was a mythical hero after whom Hereward of Bourne and other Saxons were named.[7]

This story has many points of interest which can be followed up by those who care to do so. I shall leave it there, but before passing from the subject of 'family tradition' shall ask those who believe in it one question: Can any one of them produce a single fact about his great-grandfather which has not been placed on record? My great-grandfather, the first Lord Raglan, was a man of some distinction, and yet, though I often visited his daughters, who lived well on into the present century, I know practically nothing about him that is not in print.

'Local Tradition.'

Sir G. L. Gomme, in his *Folklore as an Historical Science*, attempts to establish the historical value of local tradition, but is constrained to admit that it may often be mere false history, started by the local antiquary. In my view, with certain exceptions which I shall come to later, it is always false history. Let us take an example. There is a well-known folk-story of the Faithful Hound, variants of which are found in many parts of Europe, Asia and Africa.[8] It is probably derived from a rite, similar to that described in Genesis xxii, by which a pretence is made of sacrificing a child, and an animal substituted at the last moment. The popularity of this story in Wales, and the fact that in an English version the dog

[7] *D.N.B.*, s.v. 'Hereward'; J. H. Round, *Feudal England*, p. 161; *The Ancestor*, vol. ii, pp. 109–113.

[8] S. Baring-Gould, *Curious Myths of the Middle Ages*, pp. 134 *seq.*

is called Kill-hart, apparently led, in the late eighteenth century, to the localisation of the story at Beddgelert, a village near Snowdon, the name of which is thought to mean the grave of Kelert, an early saint. The fact that Llewellyn is a popular North Welsh hero, and the enterprise of a local innkeeper, who about 1830 set up a tombstone at a suitable spot, were sufficient to establish a ' tradition ' which was accepted by thousands, not merely of the ignorant but of the learned.[9]

Where local traditions are not the result of such guesswork, they usually arise from ignorance and superstition. Krappe[10] tells us that ' the dolmens of France and the British Isles are the work of fairies ; ' the remains of the Roman limes are attributed by German peasants to ' the Devil, who divided the earth with Our Lord, and erected the wall ' to mark the boundary. The ruins of the Roman amphitheatres of ' Southern France are called the " palais de Gallienne," Galienne being ' a powerful Moorish princess and the wife of Charlemagne. To the ' fellahin of modern Egypt the pyramids are the work of the jinn.' Those who believe that Caesar's Camp was constructed by Cæsar are morally bound to believe that the Devil's Dyke was constructed by the Devil. Cæsar's Camp in Sussex, excavated by General Pitt-Rivers, proved to be of Norman origin.

But while we find on the one hand that local tradition, whenever it can be checked, proves to be untrue, we find on the other that real events never find their way into local tradition. Near where I live are the remains of a score of castles, many of them the scene of historic sieges and other events. Yet not only are there no authentic traditions about these events—there are no traditions at all.

I will conclude my remarks on this part of the subject by noting that there is one possibility of a genuine local tradition—where the repetition of a ritual drama at a given spot gives rise to the belief that the events enacted in the drama really occurred at that spot. There are various parts of the world, particularly Ancient Greece, in which this type of tradition has probably come into existence.

Tradition and English History.

Those writers who have tried to establish the historicity of tradition have invariably, so far as I can learn, adopted the method of taking some period the history of which is totally unknown, examining the traditions which they assume to belong to that period, striking out all miraculous or otherwise improbable incidents, and then dilating upon the verisimilitude of the residue. I shall follow a totally different method. I shall take a period the history of which is known, the feudal age in England, and see what tradition has had to say about that. According to the usually accepted theories, outstanding personalities in the history of a country never fail to leave their mark on tradition. Now who were the outstanding personalities of the period in question ? No one, I suppose, will object to the inclusion of William the Conqueror and Edward I. The Norman Conquest in the one case, and the conquest of Simon de Montfort,

[9] J. Jacobs, *Celtic Fairy Tales*, pp. 261–264. [10] *Op. cit.*, p. 75.

Wales and Scotland in the other, cannot have failed to create a tremendous impression at the time, and this impression, according to the theory which has been repeatedly applied to the *Iliad*, for example, should have perpetuated itself in tradition. Yet what traditions do we find? Of William the Conqueror, that he fell on landing, and that he destroyed a number of towns and villages to make the New Forest. Of Edward I, that his life was saved by his queen, and that he created his newly born son Prince of Wales. All these traditions are completely devoid of historical foundation. Of the real achievements of these two great monarchs tradition had nothing to say whatever.

Similarly the only traditions of Henry II and Richard I are the fabulous tales of Queen Eleanor and Fair Rosamund, and of Blondel outside the castle.

With the traditional accounts of Henry V, those that have been made famous by Shakespeare, I shall deal at greater length. They tell us that he spent his youth in drinking and debauchery, in and about London, in company with highwaymen, pickpockets, and other disreputable persons; that he was imprisoned by Chief Justice Gascoigne, whom after his accession he pardoned and continued in office; and that on his accession his character, or at any rate his conduct, changed suddenly and completely. The authorities for these stories are Sir Thomas Elyot's *The Governor* (1531) and Edward Hall's *Union of the Noble and Illustrious Houses of Lancaster and York* (1542). These two highly respectable authors seem to have relied largely on matter already in print, some of it dating from within fifty years of Henry V's death. I know no argument for the historicity of any traditional narrative which cannot be applied to these stories—yet there is not a word of truth in any of them.

The facts are these. In 1400, at the age of thirteen, Henry became his father's representative in Wales, made his headquarters at Chester, and spent the next seven years in almost continuous warfare with Owen Glendower and his allies. In 1407 he led a successful invasion of Scotland. In 1408 he was employed as Warden of the Cinque Ports, and at Calais. In the following year, owing to his father's illness, he became regent, and continued as such until 1412. During this period his character as a ruler was marred only by his religious bigotry, and what seems to be the only authentic anecdote of the time describes the part he played at the burning of John Badby the Lollard. In 1412 an attempt was made to induce Henry IV, whose ill-health continued to unfit him for his duties, to abdicate, but his refusal to do so, together with differences on foreign policy, led to the withdrawal of the future Henry V from court, probably to Wales, till his father's death a year later. He did not reappoint Sir William Gascoigne as Chief Justice, and there is no truth in the story that the latter committed him to prison.

These facts are drawn from the *Dictionary of National Biography*, which sums up the question by saying that 'his youth was spent on the battle-'field and in the council chamber, and the popular tradition (immortalised 'by Shakespeare) of his riotous and dissolute conduct is not supported by 'contemporary authority.' According to Sir Charles Oman, 'his life was 'sober and orderly. . . . He was grave and earnest in speech, courteous

'in all his dealings, and an enemy of flatterers and favourites. His sincere 'piety bordered on asceticism.'

Even had there been no contemporary records of the youth of Henry V, there are points in the account adopted by Shakespeare which might lead the sober critic to doubt its veracity. The first is that it would be, to say the least, surprising that a man should be an idle and dissolute scapegrace one day, and the first soldier and statesman of his age the next. The second is that the stories belong to an ancient and widespread class of folk-tales. Had, however, our critic ventured to express his doubts, with what scorn would he not have been assailed by believers in the historicity of tradition! 'Here,' they would have said, 'is an impudent fellow who 'pretends to know more about the fifteenth century than those who lived 'in it. The facts which he dares to dispute were placed on record by 'educated and respectable persons, the first historians of their day. 'Could anything be more absurd than to suppose that they would invent 'discreditable stories about a national hero, at a time when all the facts 'of his career must have been widely known? No reasonable person can 'doubt that Falstaff was as real as Piers Gaveston.' As we have seen, however, the only evidence for Falstaff's existence is tradition, and tradition can never be evidence for an historical fact. He is a purely mythical character, who plays Silenus to Henry's Dionysus, as does Abu Nawâs to the Dionysus of Harûn ar-Reshîd.

The assimilation of the king to Dionysus no doubt goes back to a time when an aspirant to the throne had to perform various rites and undergo various ordeals, but whether these stories had previously been told of other English princes, and became permanently attached to Henry V through the invention of printing, or whether they were recently introduced from classical sources, I have no idea.

It may be objected that Henry V, an historical character, appears in tradition, and that tradition is therefore to that extent historical; but this is not so. The characters in a traditional narrative are often anonymous. When named they may be supernatural beings, or persons for whose existence there is no real evidence. When the names of real persons are mentioned, these names form no part of the tradition, but merely part of the machinery by which the tradition is transmitted. Just as the same smart saying may be attributed to half a dozen wits in succession, so the same feat may be attributed to half a dozen heroes in succession, but it is the anecdote or feat which, if it is transmitted from age to age, becomes a tradition, and not the ephemeral name. The name selected is that of some prominent person whose memory is fading; who has been dead, that is to say, for about a hundred years, or less if the real facts have never been widely known. His name remains attached to the tradition till some other suitable person has been dead for a suitable length of time.

This explains certain facts which have puzzled Prof. Gilbert Murray, who asks: 'Why do they [*sc.* the Homeric poets] refer not to any war-'fare that was going on at the time of their composition, but to war-'fare of forgotten peoples under forgotten conditions in the past? . . . 'What shall one say of this? Merely that there is no cause for surprise. 'It seems to be the normal instinct of a poet, at least of an epic poet. The

'earliest version of the *Song of Roland* which we possess was written by an 'Anglo-Norman scribe some thirty years after the Conquest of England. 'If the Normans of that age wanted an epic sung to them, surely a good 'subject lay ready to hand. Yet as a matter of fact their great epic is all 'about Roland, dead three hundred years before, not about William the 'Conqueror. The fugitive Britons of Wales made no epic to tell of their 'conquest by the Saxons ; they turned to a dim-shining Arthur belonging 'to the vaguest past. Neither did the Saxons who were conquering them 'make epics about that conquest. They sang how at some unknown 'time a legendary and mythical Beowulf had conquered a legendary 'Grendel.' [11]

The true explanation has nothing to do with instinct ; it is that epic poetry, like other forms of traditional narrative, deals with ritual drama, and not with historical fact. Real people and events can only be identified with ritual drama when their memory has become vague. Roland could not have been made to fall at Hastings before about 1166, and by that time the form of the epic was fixed in writing. What we learn from the *Song of Roland* are old traditional tales which were probably attached to Charlemagne about a hundred years after his death. The real facts of his career, like all historical facts, have been, and could only be, ascertained from contemporary written records.

In this connection Dr. Leaf remarks : 'When they [the Normans] 'crossed the Channel to invade England, they seem to have lost all sense of 'their Teutonic kinship with the Saxons, and it is doubtful if they even 'knew that their name meant Northmen. The war-song which Taillefer 'chanted as they marched to battle was not a Viking saga, but the song of 'Roland.' [12] He realised that a people can completely forget its origin within a hundred and sixty years—yet still believed in the continuity of historical tradition !

The Ritual Drama.

If, as I hold, the traditional narrative is always an account of a ritual drama, then the present incidence of traditional narratives must coincide with the present or past incidence of ritual dramas ; that is to say that in areas where traditional narratives are numerous and elaborate, ritual dramas must be, or have been, numerous and elaborate, and where they are few, simple, or non-existent, ritual dramas must be, or have been, few, simple, or non-existent. And, conversely, where we find ritual dramas, there we must expect to find corresponding traditional narratives.

A preliminary survey of the world suggests that our expectations would be fulfilled. Thus among the Yuma Indians of the Colorado the principal ritual drama is the creation rite, and the principal traditional narrative is a description of that rite in quasi-historical language. We find a similar drama and a similar narrative among the Marindineeze of Dutch New Guinea. Among the Shiluk of the Upper Nile the principal ritual drama is the installation of the king, and the principal traditional narrative is an

[11] Gilbert Murray, *The Rise of the Greek Epic*, pp. 52–55.
[12] W. Leaf, *Homer and History*, p. 46.

account of this installation, describing how the image of the mythical Nyakang is brought to Fashoda as if a real god-king came to Fashoda.

Where these facts are realised, they are usually attributed to commemoration. I have elsewhere [13] pointed out the absurdity of the commemoration theory. Why should people put themselves to all this trouble without hope of benefit, and why should they expect to benefit by commemorating the death of some ancient king?

No one will deny that the ritual drama in Ancient Greece was of the highest religious importance. The plays and fragments of plays which have come down to us represent only a very small fraction of those that were written, and probably there were thousands more which were never written. These plays made up a large part of the religious life of the Ancient Greeks, and there are survivals of them among the Greek peasantry to this day. Now one of the leading incidents represented at the ritual drama at Athens was the death of Agamemnon. Is there any conceivable reason why the murder of a king of Mycenæ should have been a leading incident in the ritual drama at Athens? There can be little doubt that it was the dramatised version of a ritual of human sacrifice, a ritual once practised all over Greece, by which the old king was ceremonially killed by his successor. The myth was localised, but the ritual was universal. But while king-killing myths were localised all over Greece, we find no battle and siege myths except those localised at Troy and Thebes. I venture to conjecture that Troy was once the only place where the war ritual was performed; that all the Greeks used to assemble there periodically for a great religious festival, and that later a similar festival was established at Thebes for those of the peninsular Greeks who had no ships.

But let us turn to Western Europe. In his *Chances of Death* Prof. Karl Pearson showed what an important part was taken by the miracle or mystery plays in the religious life of mediæval Europe. In some cases these plays covered all time from creation till doomsday, and took as long as eight days to perform. They took place in the churches, and while heaven was represented by a gallery in which sat those who took the parts of the Trinity and the angels, Satan and his host appeared from below the main stage. Prof. Pearson concluded that these dramas replaced heathen dramas of similar character. He says: 'That the old heathen 'religion was an essentially dramatic one can scarcely be doubted; we 'have proof enough not only in written statements, but in a vast number 'of folk-customs of dramatic origin. We find many cases in which heathen 'customs were introduced into Christian churches . . . both monks and 'nuns indulged in dances and masquerades directly connected with 'heathen festivals.' [14]

The facts which were noted by Prof. Pearson find confirmation and amplification in *The Culture of the Teutons*, by a Danish writer, Vilhelm Gronbech, who deals at length with the importance of the ritual drama in the heathen religion, shows how the incidents of the dramas can be reconstructed from the traditional narratives, and points out the absurdity of trying to translate these narratives into terms of history.

[13] *Jocasta's Crime*, p. 44.

[14] *Op. cit.*, vol. ii, pp. 281–282.

'The legends will not tell us what happened some year or other according to chronology; in our craving for a kernel of historical truth in the myths, we naïvely insinuate that the myth makers ought to think in a system unknown to them, for the benefit of our annalistic studies. . . . Time is, in our experience, a stream of events descending from the unknown mists of beginning and running in a continuous flow down the future into the unknown; to the men of the classical ages the actual life is the result of a recurrent beginning and has its source in the religious feast. The festival consists of a creation or new birth outside time, eternal it might be called if the word were not as misleading as all others and as inadequate to describe an experience of a totally alien character. When the priest or chieftain ploughs the ritual furrow, when the first seed is sown while the story of the origin of corn is recited, when the warriors act the war game, they make history, do the real work, fight the real battle, and when the men sally forth with the plough or the seed or the weapons, they are only realising what was created in the ritual act.'[15]

According to Gronbech, then, the myths and legends of the North have their origin in the world of ritual drama, a world in which the terms of history are quite meaningless. Other writers are moving in the same direction. Mr. C. B. Lewis, in his *Classical Mythology and Arthurian Romance*, seeks to show the ritual origin of the Arthurian legends, while M. P. Saintyves, in his *Les Contes de Perrault et les Récits Parallèles*, performs the same service for such tales as *Cinderella* and *Bluebeard*. Prof. S. H. Hooke and his colleagues have recently traced the connection between *Myth and Ritual* in Semitic lands.

It will be seen, then, what a variety of fortunes has befallen the ancient ritual dramas. Some have been converted to Christianity; some have been rationalised into pseudo-history; others have degenerated into fairy tales. There are, however, some which survive, or survived till recently, in something like their original form. Let us take, for example, the cycle of Robin Hood, which forms the most important body of English and Scottish traditional narrative. Attempts have of course been made to turn him into an historical character, but he remains the god of the tree, a figure of world-wide importance. Hód's Oak is the name given in an Anglo-Saxon charter to a place in Worcestershire, and he owns hills, rocks, caves and wells in Yorkshire, Lancashire, Nottinghamshire, Derbyshire, Shropshire and Somerset. His story has been localised in Nottinghamshire, Yorkshire and Cumberland, as well as in Scotland, and he has been supposed to have lived in the twelfth, thirteenth and fourteenth centuries, and sometimes to have been earl and sometimes churl. But wherever and whenever he lives, he always has his Maid Marian, his Little John and his Will Scarlet, since it is the incidents of the ritual drama, and not its setting, which matter. That he was the hero of such a drama there can be no doubt. We are told [16] that in the fifteenth century the May celebration was called 'Robin Hood's festival,' and that he was 'one of the mythical characters whom the populace was fond of personating in the semi-dramatic devices and morris-dances performed at that season.' In Scotland he was as popular as in England, and in 1577 the Scottish Par-

[15] *Op. cit.*, vol. ii, pp. 226, 261. [16] *D.N.B.*, s.v. Hood, Robin.

liament requested the King to prohibit plays of 'Robin Hood, King of May' on the Sabbath. In France Robin des Bois and Marian are found in the thirteenth century as characters in the Whitsuntide *pastourelles*—a fact which rather suggests that the whole story came to England with the Normans, more especially as in other northern lands this drama took the somewhat different form which is familiar to us as the story of William Tell. The latter was long believed to be an historical character, but the story is now recognised as a widespread myth.

Before leaving this part of the subject I should like to touch on two forms of the traditional narrative which are much relied upon by those who believe in the historicity of tradition—the Icelandic saga and the quasi-historical traditions of Polynesia. The most famous of the Icelandic sagas is probably that of *Burnt Njal*, and the central incident in it is the burning of Njal and his sons in their house. When, however, we come to examine this story, we find that it is merely a variant of the Irish story of Naisi. Let us take one incident. When Skarphedinn and his brothers are shut up in the burning house, Gunnar, a man whose relatives Skarphedinn has slain, climbs up and looks over the wall; Skarphedinn throws a tooth at him, hitting him in the eye, and causing his eyeball to fall out on to his cheek. Naisi and his brothers are shut up in a house, and before Conchobar orders his men to set fire to it he sends Trendorn, a man whose relatives Naisi has slain, 'to see whether her own shape 'remained on Deidre.' He peeps through a small upper window; Naisi throws a draughtsman at him and hits him in the eye, so that his eyeball falls out on to his cheek. I have no doubt that Naisi and Skarphedinn are names for a northern variant of Heracles, whose adventures and death formed part of the ritual drama.

For Polynesian traditions I shall rely on Mr. Percy Smith, and he, though he firmly believes in the historicity of these traditions, nevertheless gives us a number of hints that they are really accounts of ritual drama. Thus he tells us that 'much of the old history of the Polynesians was 'regarded as sacred, and its communication to those who would make an 'improper use of it would inevitably—in the belief of the old priests—'bring down disaster on the heads of the reciters. . . . This teaching '[*sc.* of the tribal lore] was accompanied by many ceremonies, incanta-'tions, invocations, etc. . . . There was a special sanctity attached to 'many things taught; deviation from the accepted doctrine, or history, was 'supposed to bring down on the offender the wrath of the gods.'[17] He later tells us that 'there was a class of roving actors and players, who were also the custodians of much of the historic traditions,' and that 'the 'history of Onokura is a very remarkable one . . . the narrative is inter-'spersed with songs and recitative, which would take many hours in 'delivery. It is, in fact, a regular "South Sea opera."'[18]

If these traditional narratives were really history, and if the teaching of history followed the same course in this country as it is alleged to in Polynesia, we should find professors imploring their pupils not to make an improper use of the Constitutions of Clarendon; boys learning the names of Henry VIII's wives with incantations and invocations; people con-

[17] S. Percy Smith, *Hawaiki*, pp. 14–15. [18] *Ibid.*, pp. 138, 222.

victed of blasphemy for mixing up Thomas Cromwell with Oliver; and the history of the Corn Laws related with vocal and instrumental accompaniment. These traditions are sacred, not because they contain historical facts, which never are and never could be sacred, but because they are ritual, which is always sacred.

Features of the Traditional Narrative.

I propose to conclude by referring to a number of features which are found in traditional narratives of all descriptions, and which can be explained, and in my view only explained, on the supposition that these narratives are all accounts of ritual drama.

(1) The narrative is invariably dramatic. This is, of course, characteristic of the drama, but not of history, which is seldom dramatic.

(2) Though the characters are often represented as coming from different countries, they all speak the same language. In tradition, as on the stage, interpreters are unknown.

(3) The action of the narrative is often carried on by means of songs and rhymes; this never happens in real life.

(4) The traditional narrative, unlike history, always contains a great deal of conversation. If all the authentically recorded utterances of every English king from the eleventh to the fifteenth centuries were put together, they would not amount to the utterances of the meanest stage hero.

(5) In tradition the costume of the characters is often described in detail. It is, of course, important that the leading characters in the ritual drama should be correctly dressed, but we are very seldom told what historical characters wore.

(6) Traditional narratives often have a conventional setting, such as the gateway of a city, the doorway of a palace, or outside a hut in the forest. In real life people seldom give out their secrets at such places, but in tradition they make a practice of it.

(7) In the traditional narrative the hero often spends what he supposes to be a day in a cave or on an island, and finds on his return home that he has been away a whole year. This does not occur in real life, but on the stage a year often elapses between Act I and Act II.

(8) The characters in the traditional narrative always remain the same age. We see this clearly in Homer. Helen's amorous adventures last for about thirty years, but at the end she is still a young and beautiful girl. Nestor, at the beginning of the siege of Troy, is a hale but very old man; at the end of the siege he is still a hale but very old man, and he returns home and goes on being a hale but very old man. In the same way Njal, when we first meet him, is a wise old man to whom people go for advice; forty years later he is still a wise old man to whom people go for advice. An old Helen, and a young Nestor or Njal, are as unthinkable as an old Columbine or a young Pantaloon.

(9) Not only do the characters remain at the same age, but they are all contemporaries. Prof. Gilbert Murray has noticed this; he says: 'There is an extraordinary wealth of tradition about what we may call 'the Heroic Age. Agamemnon, king of Mycenæ and Argos, Priam, 'king of Troy, and the kings surrounding them, Achilles, Aias, Odysseus,

'Hector, Paris, these are all familiar household words throughout later 'history. They are among the best-known names of the world. But 'how suddenly that full tradition lapses into silence! The Epic Saga 'can tell us about the deaths of Hector, of Paris, of Priam; in its later 'forms it can give us all the details of the last destruction of Troy. Then 'no more; except a few dim hints, for instance about the descendants of 'Æneas.

'It is more strange in the case of Mycenæ and Sparta. Agamemnon 'goes home in the full blaze of legend; he is murdered by Ægisthus and 'Clytemnestra, and avenged by his son Orestes; so far we have witnesses 'by the score. But then? What happened to Mycenæ after the death 'of Ægisthus? No one seems to know. There seems to be no Mycenæ 'any more. What happened to Sparta after Menelaus and Helen had 'taken their departure to the islands of the blest? There is no record, 'no memory.

'... It is the same wherever we turn our eyes in the vast field of Greek 'legend. The "heroes" who fought at Thebes and Troy are known; 'their sons are just known by name or perhaps a little more; Diomedes, 'Aias, Odysseus, Calchas, Nestor, how fully the tradition describes their 'doings, and how silent it becomes after their deaths!' [19]

We find the same phenomenon in many parts of the world, and the explanation is, in my view, a simple one. When the drama is over, the curtain goes down.

(10) The fact has been noted by Prof. Chadwick that 'the religion 'of the Heroic Ages is predominantly the worship of gods, while in his- 'toric Greece and Scandinavia, etc., forms of chthonic worship are more 'prominent, and survive for centuries.' [20] Supernatural beings, to be brought on to the stage, must of course be represented in human or animal form.

(11) Among the commonest of the miraculous events which figure so largely in traditional narrative is shape-changing. In the *Völsunga Saga* Freya puts on the gear of a crow and flies off. Sigmund puts on a wolf-skin and becomes a wolf. These feats are easy on the stage, but difficult in real life. Hartland notes that 'the dress (which transforms 'the heroine into a swan, etc.) when cast aside seems simply an article of 'human clothing, often nothing but a girdle, veil or apron; and it is only 'when donned by the enchanted lady, or elf, that it is found to be ... a 'complete plumage.' [21] The stage properties of the ritual drama must often have been few and simple.

(12) There are few traditional narratives which do not include a king and queen. Prof. Pearson explained this by supposing that Europe was once divided into a vast number of tiny kingdoms, but the real reason is that the king and queen are the centre of all ritual, and must therefore be represented in all ritual drama.

(13) A point which has been noticed by various writers is that the battle in tradition is always a series of single combats. Prof. Chadwick explains this [22] by saying that the possession of armour constituted an

[19] *Op. cit.*, pp. 52–55.
[20] *Op. cit.*, p. 424.
[21] *Op. cit.*, p. 301.
[22] *Op. cit.*, p. 339.

overwhelming advantage, and that the object of the battle was to kill the leaders, who were expected to distinguish themselves by personal bravery. The same considerations, however, apply equally to feudal times, yet we never find feudal monarchs engaging in single combat.

The theory put forward by Ridgeway to account for this and similar facts was that people who cannot write keep accurate historical records which they transmit orally, but that instead of expressing themselves in straightforward language they personify their own and neighbouring tribes, and then represent collective activities in terms of individual acts. The theory seems to be that at a certain stage in our culture we should have described the English conquest of Ireland by saying that Britannia jumped a ditch into her neighbour's garden, and the Battle of Trafalgar by saying that Britannia quarrelled with Gallia, and threw her bucket down the well.

In criticising this theory, Mr. A. Nutt asked : ' Is there such a thing as ' historic myth at all ? Do men commemorate tribal wanderings, settle- ' ments, conquests, subjugations, acquisitions of new forms of culture, ' or any of the other incidents in the collective life of a people, in the form ' of stories about individual men and women ? I do not for one moment ' deny the possibility of their doing so ; all I ask for is evidence of the fact.' [23] I cannot find that anyone has ever produced any evidence, yet the theory is still widely held, and was much later put forward by Prof. Murray, who tells us that he strongly suspects the lists of men slain by the heroes of the *Iliad* to be tribal records, condensed, and, ' of course,' transferred from their original context. He has already given us an example of one of these ' tribal records.' In the *Iliad* it is said that Phæstus was slain by Idomeneus, and fell from his chariot with a crash. On this Prof. Murray comments : ' Idomeneus is the king of Knossos in Crete, and ' Phæstus is only known to history as the next most famous town in the ' same island. That is to say, Phæstus *is* the town, or the eponymous ' hero of the town. So we have in this passage a record of a local battle ' or conquest in Crete, torn up from its surroundings and used by the poet ' to fill in some details of slaughter in a great battle before Troy.' [24]

Even if we admitted the possibility of historic myth, it would be difficult to explain why a town should be represented as falling from a chariot ; why an eponymous hero should be invented for one town but not for the other ; and why the poet of the *Iliad* should have recourse to Cretan records in order to fill in details of a battle before Troy, seeing that in more important cases he makes use of ' mythological changes and false ' identifications.' [25] It is difficult to acquit Prof. Murray of treating those portions of the *Iliad* which fit in with his theories as ' real history,' and those which do not as ' the emptiest kind of fiction.' [26] Sir William Ridgeway and Dr. Leaf rendered themselves liable to a similar charge. The reason for the single combats in tradition is that the original ritual combat was between the king and his challenger. It was this tradition which induced Shakespeare, with his habitual disregard of historical fact, to make Henry IV fight a single combat with Douglas.

[23] *Folklore*, vol. xii, p. 339.
[24] *Op. cit.*, pp. 232–234.
[25] *Ibid.*, p. 229.
[26] P. 233.

(14) Another feature of the traditional narrative is that prophecies always come true; that advice, except in certain special circumstances, is always taken; that people frequently embark on enterprises which they well know will prove disastrous; and that, as Prof. Chadwick notes, the characters are always boasting of what they have done and what they are going to do. The reason is that all present at the ritual drama are participants in the drama, and in order that they may add their share of luck to the drama and draw their share of luck from it, it is essential that they should fully realise what is going on. And this brings me to my last point.

(15) In many forms of the traditional narrative there is a character who takes the parts of prompter and stage manager. It is his business to tell the actors what to do, and when necessary to tell the audience what is being done. The heathen ritual drama consisted largely of acts which were regarded by the Church as sinful, and in the gradual process of converting these dramas to Christianity we find the prompter coming to be identified with the Devil. It is clear in *Faust*, for example, that Mephistopheles is nothing more than the prompter; without him there would be no drama at all. Similarly, in that wonderful play *The Miracle*, in which we are shown many of the features of the ritual drama, the Spielmann plays the part of prompter and stage manager.

In the *Völsunga Saga* the part is taken by Odin, who speaks the prologue and epilogue, and intervenes at critical moments to direct the action. Odin, we are told, was represented as an old man with one eye and a broad-brimmed hat; where could he have been so represented except on the stage? In the Arthurian legends it is Merlin who is the prompter. He is always telling the actors what to do and the audience what is going to happen.

In the Homeric dramas there does not seem to have been an individual prompter. The gods apparently sat, like the Trinity of the miracle plays, on a raised platform. They announced what was going to be done, and descended, when necessary, to direct the actors.

Conclusion.

Ridgeway assures us that unless we are prepared to maintain that both Herodotus and Thucydides are utterly untrustworthy, we must accept what they tell us of Greek prehistory; but we are in reality faced with no such alternative. We may well believe that these writers, like Ridgeway himself, were genuine seekers after truth, but that, also like him, their methods were totally unscientific. He, and nearly all the other writers whom I have quoted, not merely start by assuming what they wish to prove—namely, that the *Iliad* is historical—but they rely almost entirely on internal evidence. It would be possible to prove by this method the historical truth of any novel. When Homer says that Ithaka is an island, they give him full marks for geography. When he says that it is rich in wheat, he does not lose any marks: they merely conclude—at least Dr. Leaf did—that in Homer's time some other island was called Ithaka. This kind of thing is not science at all: it is merely a parlour game. Unfortunately, however, anthropologists have been taught to take it seriously, and are now

engaged, all over the world, in the hopeless attempt to extract history and geography from the traditional narratives, instead of putting these to their proper use, which is to act as a guide to the rites of the people concerned, and so to their beliefs and ideas.

The only sure foundation for the edifice of science is the concrete of ascertained fact, reinforced by the steel rods of universally tested theory. The ground upon which the edifice of social anthropology had to be built was encumbered not merely by the ruins of ancient superstitions, but also by the jerry-buildings of pseudo-history and pseudo-psychology, and many anthropologists have believed that these survivals could be incorporated in the new edifice. The result has been that social anthropology has been allotted, very properly, a low place among the sciences. It will never occupy what should be its proper place until a vast quantity of pre-scientific and pseudo-scientific rubbish has been cleared from its path, and if this address helps in the smallest degree to bring about this clearance, it will have more than achieved its object.

SECTION I.—PHYSIOLOGY.

THE ACTIVITY OF NERVE CELLS

ADDRESS BY

PROF. E. D. ADRIAN, F.R.S.,

PRESIDENT OF THE SECTION.

Since the biologist seeks to understand life, he cannot be accused of lack of courage. But he can find out a great deal without approaching too near the central problem. He can find out how the living cell develops and how it behaves ; he can follow many of the physical and chemical changes which take place in it, and could follow more if cells were not so inconveniently small. The immediate problems of the physiologist may be still further removed from the problem of life. They may deal, for instance, with the mechanics of the vascular system or with the physical chemistry of blood pigments. But most of us aim at explaining the working of the body in terms of its constituent cells, and feel that this is a reasonable aim even though we must take the cell for granted. Is it a reasonable aim when we are dealing with the working of the nervous system ? That is the problem which I shall discuss this morning.

The nervous system is responsible for the behaviour of the organism as a whole : in fact, it makes the organism. A frog is killed when its brain and spinal cord are destroyed : its heart still beats and its muscles can still be made to contract, all the cells of its body but those of the brain and cord are as fully alive as they were before ; but the frog is dead and has become a bundle of living tissues with nothing to weld them into a living animal. This integrative action of the nervous system, to use Sherrington's classical phrase, we may be able to explain in terms of the reactions of the constituent nerve cells. We can at least discuss the point as physiologists. But the human organism includes a mind as well as a body. It may be best to follow Pawlow and to see how far we can go without bringing in the mind, but if the reactions of our nerve cells are to explain thought as well as action we must face the prospect of becoming psychologists and metaphysicians as well. Fortunately we need not yet go to such extremes. There are problems enough on the physiological plane, and they are made all the more interesting by this hint of mystery in the background.

The nervous system, the brain, spinal cord and peripheral nerves, is made up of a large number of living cells which grow, maintain themselves by the metabolism of food-stuffs, and carry out all the complex reactions of living protoplasm. In this there are enough problems for anyone ; but we are concerned not with the general properties of living cells but with those special properties which enable the cells of the

nervous system to perform their functions. Their function is to make the organism respond rapidly and effectively to changes in its environment, and to achieve this they have developed a specialised structure, and a complex arrangement in the body. They send out long threads of protoplasm which serve for the rapid transmission of signals, and they are linked to one another by elaborate branching connections in the brain and the spinal cord.

The Development of the Nervous System.

The mapping of this network of paths was begun many years ago, and was the first step in the analysis. No progress could have been made without it, and its results are of vital importance to neurology. We are now witnessing a fresh period of interest in the geography of the central nervous system, but the problem is not how the nerve cells and their fibres are arranged, but why they are arranged as they are. R. G. Harrison in his recent Croonian Lecture recalled the time when he first cultivated living nerve cells outside the body. That experiment made twenty-three years ago, marks the new epoch better than any other, for, besides introducing the method of tissue culture, it settled a long and bitter controversy as to the origin of nerve fibres. Nowadays the most elaborate transplantation experiments are carried out by the embryologists on amphibian larvæ. Animals are produced with supernumerary limbs, eyes, noses, and even spinal cords. The growing nervous system is faced with these unusual bodily arrangements, and by studying the changes induced in it we can form some idea of the factors which determine its normal structure. A review published this summer by Detweiler gives a vivid impression of the plasticity of the developing nervous system in the hands of the experimenter. As a rule it accepts the extra limb or sense organ, links it by nerve fibres to the rest of the organism and may develop more nerve cells to deal with it. The forces which mould the nervous system seem to come partly from within the central mass of nerve cells and partly from the body outside. These forces may be chemical or electrical gradients, and often the nerve fibres seem to grow in particular directions because they cling mechanically to structures already laid down, e.g. to the main arteries of the limbs. It is unlikely that a simple formula will be found for such a complex arrangement, but the fact remains that the arrangement can be profoundly modified at the will of the experimenter. Its detail seems to depend not so much on the innate properties of particular cells as on the environment provided by the rest of the organism.

The Reactions of the Neurones.

This new embryological work supports the older in showing that the nervous system is made up of ' neurones,' cells with thread-like extensions, and that they are the only active elements in it. These elements are all cast in the same mould, but are shaped differently by the forces of development. To this we can now add the fact that all neurones seem to do their work in much the same way. The activity which they show is in some respects remarkably simple. It is essentially rhythmic : a

series of rapid alternations between the resting and the active state, due probably to rapid breakdown and repair of the surface. This at least is a fair description of the way in which the nerve fibres carry out their function of conducting messages, and we can detect the same kind of pulsating activity in the nerve cells of the brain.

The evidence comes from the analysis of minute electric changes, for cell activity sets up electrical eddies in the surrounding fluid, and these can be measured with a minimum of interference. The clearest results are given by the peripheral nerve fibres which connect the central nervous system to the sense organs and the muscles. The nerve fibres are conveniently arranged in bundles to form the nerve trunks : each fibre is an independent conducting path and there may be a thousand such paths in a fair-sized nerve, but it is not a difficult matter to study what takes place in the single fibre when it conducts a message. We may begin with an external stimulus acting on a sense organ, a structure which includes the sensitive ending of a nerve fibre as an essential part. The ending is excited by the stimulus, the delicate equilibrium of its surface is upset and the disturbance tends to spread along the fibre. The spreading is an active process : it takes place because the fibre has a store of energy ready to be liberated at a moment's notice, and because the changes which attend its liberation at one point upset the balance at the next point and cause the same activity there. The spread of a flame along a fuse is a well-worn analogy. But the nerve fibre is so constituted that a disturbance at any point is almost immediately cut short. The change spreads along it as a momentary wave—a brief impulse followed inevitably by a brief interval of rest and recovery. If the sense organ remains excited a second impulse passes up the fibre, and then another and another as long as the stimulus is effective. The impulses in a given nerve fibre are all alike in magnitude, rate of travel, etc., but the frequency at which they recur depends on the intensity of the stimulus, rising sometimes as high as 300 a second in each fibre, or falling as low as 10. All the nervous messages take this form ; the central nervous system is continually bombarded by trains of such impulses passing along the slender threads of protoplasm from the sense organs, and is continually sending out trains of impulses to the muscles.

The conducting threads or nerve fibres are exceedingly insensitive to changes in their environment : their endings in the sense organs are exceedingly sensitive. The sole function of the ending is to act as the trigger mechanism for firing off the impulses, and the sole function of the nerve fibre is to carry the message without distortion. Both are specialised parts of the neurone with specialised reactions, but it is important to note that these reactions are not peculiar to the nervous system. Muscle fibres, developed from the mesoderm and specialised for contraction, conduct impulses which seem to differ merely in their time relations from those in nerve fibres, and they can also be made to behave like the sensory endings by treatment with various salt solutions. In sodium chloride, for instance, a series of impulses will be set up in a muscle fibre when it is stretched, as they would be in one of the sense organs whose sole duty is to act as 'stretch receptors.' The muscle fibre makes

a poor copy of the nervous mechanism, for it reacts jerkily and is often damaged in the process, but the ground-plan of the mechanism is the same.

Thus in the activities concerned in the rapid conduction and in the setting up of rhythmic trains of impulses, it does not appear that the cells of the nervous system have properties not shared in some degree by other tissues.

So far we have only considered what happens in nerve fibres. We can tap the messages which pass along the wires between the front line and headquarters, but this does not tell us how they are elaborated there. A great deal has been found out already by the analysis of reflexes—i.e. by sending in a known combination of signals and finding what signals come out to the muscles; indeed, the great part of Sherrington's work on the spinal reflexes and Pawlow's on the brain has been carried out in this way. An account of the central nervous system which does not include a full discussion of such important work is like the tragedy of Hamlet without the Prince of Denmark; but the results are so well known that I shall deal instead with a recent line of attack of an entirely different kind. This relies on the fact that nervous activity, in the central grey matter as in the peripheral nerves, is accompanied by electric changes. They seem to be a reliable index of the underlying activity, and by recording them we come a step nearer to the main problem. The chief difficulty is to interpret the records. In the cerebral cortex, for instance, very large electric oscillations are constantly occurring, except in the deepest anæsthesia, but they vary from moment to moment and from place to place, and it is only in the visual cortex that they are under a fair degree of experimental control. Here they can be produced by shining a light in the eye (Fischer and Kornmüller) or stimulating the optic nerve (Bartley and Bishop), and the prospects of analysis are more hopeful. But at the moment the most significant feature of these records from the brain lies in the appearance of the waves. Whenever a group of nerve cells is in action, in the cerebral cortex, the brain stem or the retina, and whether the nerve cells in question belong to a vertebrate, or an insect, the waves are alike in general form. Instead of the abrupt spikes which appear in a record from a nerve fibre when a train of impulses passes down it, we have more gradual potential changes which form a series of waves of smooth contour. In the simpler structures where most of the neurones are acting in unison the waves may have a regular rhythm (5 to 90 or more a second), which rises and falls when the stimulus changes in intensity. It is often possible to make out both the abrupt nerve fibre impulses and the slower nerve cell waves, and to show that they occur together. In the cerebral cortex of an anæsthetised animal there is much more variety and less orderly repetition; the waves usually occur at irregular intervals; they vary in size and duration, and some of them may last for half a second or even longer.

Nerve cell waves may be the wrong name, for they are probably due to the branching dendrites and not to the cell body of the neurone; but there can be no doubt that they represent a characteristic activity of the structures which make up the grey matter. They show that the same

kind of rhythmic breakdown and repair of the surface takes place in this part of the neurone as in the nerve fibre, with the important difference that the changes develop and subside much less abruptly. The surface is not specialised for rapid conduction ; the forces which restore the resting equilibrium are less powerful and there is more tendency to spontaneous breakdown and to long periods of uninterrupted activity. We know that the activity of the grey matter is far more readily influenced by chemical changes than is that of the nerve fibre with its elaborate fatty sheath and wrappings of connective tissue, and it seems probable that both chemical and electric changes may be concerned in the spread of activity from one neurone to another. How this spread takes place is still uncertain, and it is admittedly the most important problem we have to face. In spite of this we can claim to have some of the main outlines of neurone activity. Our nervous system is built up of cells with a specialised structure and reactions, but the reactions are of a type to be found in many other cells. The rhythmic beat of the heart is probably due to surface reactions not far different from those in the group of nerve cells which produces the rhythmic movements of breathing ; and the factors, nervous and chemical, which regulate the heart beat are probably much the same as the factors which control the discharge of the neurone. We have a store of energy, replenished constantly by cell metabolism and liberated periodically by surface breakdown. The electrical gradients at the active point cause a spread of the breakdown to other regions, but sooner or later restoring forces come into play, the membranes are healed and the cycle is ready to be repeated. It is a long step from the mechanical precision of an impulse discharge in a nerve fibre to the irregularities of a record from the cerebral cortex, but there are many intermediate cases which will bridge the gap.

The Nervous System as a Whole.

As far as the units are concerned the prospect is encouraging. The difficulties begin when we come to the work of the nervous system as a whole. Many of its reactions are mechanical enough and can be explained in terms of the activity of groups of neurones, but there is much that resists this kind of treatment. It is perhaps encouraging that the difficulties are greatest when the reactions depend on the cerebral cortex, when they involve learning and memory, or, if you prefer it, habit formation and conditioning. They have been clearly stated by Lashley, and most of them can be reduced in the end to a simple formula, the failure of anatomical models of the nervous system. The revolt from the anatomical model has been growing for many years, though it may be doubted whether its sponsors ever believed in it as much as their critics suppose. It gave us diagrams of nerve centres and pathways which were valuable enough when they referred to known anatomical structure, but not when they referred, as they often did, to hypothetical centres and to pathways canalised by use. These too may exist, but they are not the whole explanation of cortical activity.

Clinical neurology is partly to blame for the emphasis laid on exact localisation. The neurologist must locate brain tumours by analysing

the disturbances they produce ; consequently he welcomes the slightest evidence of localisation of function in the cortex, and finds the anatomical model valuable for correlating his observations. Undoubtedly there are well-defined nervous pathways, clear differences in cell structure and localised activity in different parts of the brain. As a modern addition to the evidence we have Foerster's recent work on the electrical stimulation of the human cortex, and his finding that stimulation of the temporal lobe may cause sounds and words to arise in consciousness whilst stimulation of the occipital lobe gives lights or images. Bard has given another remarkable example of strict cortical localisation by his observations on certain postural reactions in the cat. These depend on a small area in the frontal region, are not affected by damage to other parts of the brain, and are permanently lost if the frontal area is destroyed. The danger nowadays is that we may pay too little attention to such facts ; but it is true, nevertheless, that the localisation is a matter of areas rather than of single neurones. This is shown by examination of habit formation, and by the remarkable way in which the nervous system adapts itself to injury.

It has often been pointed out that we learn to recognise shapes—the letters of the alphabet, for instance—however they are presented to us. The pattern of black and white made on our retina by the letter A need not fall on a particular set of retinal endings connected with particular cortical neurones. We have learnt to recognise a relation of lines and angles, a pattern of activity in the cortex rather than an activity of specific points. This kind of reaction is not due to our superior intelligence. Lashley finds it in the rat, and psychologists of the Gestalt school have pointed out examples from all manner of animals. There is the same neglect of specific neurones in the formation of motor habits, for if we have once learnt to write the letter A with our right hand, we can make a fair attempt to write it with any group of muscles which can control a pencil.

The adaptations to injury present a different aspect of the same story. An insect which has lost a leg will at once change its style of walking to make up for the loss. This may involve a complete alteration of the normal method, limbs which were advanced alternately being now advanced simultaneously ; the activities of the nervous system are directed to a definite end, the forward movement of the animal—it uses whatever means are at its disposal and is not limited to particular pathways.

When the central nervous system is injured there is more evidence of localised function, but the localisation is no hard-and-fast affair. A rat uses its occipital cortex in the formation of certain visual habits. When this part of the cortex is destroyed the habit is lost, but it can be re-learnt just as rapidly as before with what remains of the brain. A monkey's arm is paralysed if the corresponding motor area of the cortex is destroyed, but the paralysis soon passes away although there is no regeneration of the motor cortex. What is more remarkable is that the recovered functions are not associated with the development of a new visual region or motor region in the brain. Though they were originally localised there is no longer any one part of the cortex which is essential.

In reactions where there is no evidence of localisation (e.g. the learning of maze habits in the rat), Lashley finds that the important factor is the total mass of the cortex and not the presence of particular regions. The effect of an injury depends on its extent and not on its situation. It depends, too, on the amount of grey matter (nerve cells and dendrites) destroyed, and not on the cutting of connections between the different parts of the cortex. Thus the ability of the brain to form new associations, and generally to control the behaviour of the animal, depends primarily on the total area covered by the nerve cells of the cortex and their interlacing dendrites. For certain reactions it depends to some extent on the arrangement of pathways, but this arrangement is not essential. There is more localisation of function in the large brain of man than in the very small brain of the rat, for different cortical regions may be completely equivalent when they are separated by 5 mm., but not when they are separated by 100. But apart from this difference in scale it is likely that the human cortex has the same mass effect and plasticity of function.

How do the individual neurones combine to produce a system which can recognise a triangle or direct the movements of the organism with such disregard of detailed structure ? If particular neurones or pathways are not tuned to triangularity, how can the whole mass be tuned to it, and why should the tuning be more certain when the mass is greater ? Our data may be at fault and the mass effect an illusion, but there is certainly enough evidence for it to be taken seriously. Though there is no solution at the moment, I cannot believe that one will not be found—a solution which need not go outside the conceptions of physiology. It should be possible, for instance, to find out how many neurones must be combined to give a system which reacts in this way and what kind of structure they must form. The nervous systems of insects may provide the clue, for these may contain a few thousand nerve cells in place of the ten thousand million in the human brain. It is possible also to study the reactions of isolated parts of the central nervous system, to see how far their behaviour can be explained in terms of the units which compose them. The retina is an interesting example of this kind, for it contains an elaborate structure of nerve cells and dendrite connections, and has some of the reactions which we might expect from a mosaic of sensory endings, and some which depend on interaction between the different neurones. But even now we can form some idea of the way in which the grey matter can act as a whole. The electric oscillations in the cortex and in the grey matter generally are often due to a large number of units pulsating in unison. Sometimes there are several competing rhythms, and sometimes the collective action breaks down altogether, to reappear from time to time when some part of the system is stimulated to greater activity. When these collective rhythms appear the neurones are already acting as though they formed one unit. There is no need to regard the dendrites as forming a continuous network, electric forces may well bridge the gaps between them, but they may form a system in which activity can be transmitted more or less freely in all directions. The patterns of activity in a system of this kind would be like the ripples on

the surface of a pond, with the difference that some of the ripples may occur spontaneously, whilst others are due to incoming signals. Interference figures and nodes of vibration may then be all important. They would at least give a basis for the recognition of relations such as those of triangularity or squareness without the need for an excitation of specific points, and they might be formed with less distortion in a large pond than in a small one.

This does not take us very far : in fact, the major problems of the central nervous system are left in greater obscurity than ever. But no one can observe these ceaseless electrical pulsations without realising that they provide a fresh set of data and may give a fresh outlook on the working of the brain. The facts are still too uncertain to be worth treating in greater detail. But they accumulate rapidly, and several lines of evidence seem to lead in the same direction. For the present it is enough to state our problem, that of the organisation of neurones into the nervous system. It is still a physiological problem, and I hope that a solution will be found on physiological lines. If it cannot be found it will be extremely interesting to see where the breakdown occurs, and if it can it will be even more interesting to see what light it throws on the relation of the nervous system to the mind.

SECTION J.—PSYCHOLOGY.

THE STATUS OF PSYCHOLOGY AS AN EMPIRICAL SCIENCE

ADDRESS BY

PROF. F. AVELING,

PRESIDENT OF THE SECTION.

As a text for this address, I quote a statement made by a very distinguished physicist. Sir Arthur Eddington writes : ' Mind is the first and most direct thing in our experience ; all else is remote inference.' Now this statement may mean one of several things. It may mean either that we directly apprehend the mind itself as an experiencing entity, or that we know, and only know directly, phenomena, the objective mental contents and subjective states which, as at one time it was widely held, constitute our minds or consciousnesses. In this address I shall maintain that we know both, the former as an existent in every act of experience, and the latter as events within experience. And I shall maintain this for two reasons : first, because I find it to be so on introspection ; and, secondly (though this perhaps is not a psychological reason), because, unless we grant the immediate awareness of the self as existent and active, as well as phenomenal occurrences in experience, it is impossible, so it seems to me, to account for our belief in an existing external world and for many of the conceptual constructions by means of which the various sciences attempt to explain it. I do not wish to prejudge the issue of the problem, which, as you realise, is an epistemological as well as a psychological one, by asserting anything whatever with regard to the nature of this self that we experience directly ; but I do wish to assert the reality of the experience. For me at least it is as real as the sensory experience in which the physical world, including my own body, is revealed to me.

Inadequacy of Sensory Experience.

There is, then, I maintain, more in ' mind ' than the sensory experiences which form the starting-point for physical science. This begins with the phenomenological world, a world of objects so-appearing to us ; and, on the basis of this experience, abstraction made from the fact that it *is* experience, a physical universe of reference is built up in scientific thought. It is thus apparent that physical science, omitting a great deal of experience from its purview, makes a selection of experiences. Moreover, in constructing from these the physical universe, it makes use of concepts which cannot be discovered among those particular selected experiences that form its own peculiar subject-matter. What Eddington calls ' remote

inferences ' are only made possible by the occurrence of mental processes which are also experienced, though not among the crude sensory data with which physical science is primarily concerned. Thus all the sciences of Nature begin in sensory experience. They abandon this experience for conceptual construction. But they return once more to experience to verify their constructive work. For it is not only the function of science to theorise. If it did this alone, it might end in crazy hypotheses and wild speculation. Its function is also to predict and control. And only in the immediacy of experience can the accuracy of the predictions be tested, or the competence of the controls be established.

Empiricism.

I take it that an empirical science is either one which, as the term implies, is supported by the evidence of the senses, or one which is built up out of the elements of experience. Physical science, beginning and ending in sensory phenomena, is an example of the first kind ; psychology an example of the second. But the ordinary use of the term ' empirical ' limits experience to that of a sensory nature. My plea is that this limitation is an arbitrary one and due to a philosophical prejudice. There is more in experience than sensory elements. Apart from the self and its states, affective and volitional, to which allusion has already been made, there are thought-things as well as sensed-things, relations as well as elements, correlates as well as original fundaments, in experience. The universe of physical science, for example, consists of thought-things ; it is a conceptual universe erected on the foundations of a sensed one. The external world, as presented to us by contemporary science, possesses none of the glamour and richness with which it is clothed in sensory experience. It has no colour, nor sound, nor odour, nor warmth, nor extension, nor shape, nor material substance. Yet the physicists would tell us that they are dealing with ' reality ' ; and that ' reality ' in itself is not what we naïvely suppose it to be. The world that has successively been conceived as a world of extended and solid objects, a world of atoms, of electrons and protons, of wave motions, is more physically ' real ' for physics than the everyday world in which we consciously live. It must be so, for indeed it is looked upon as the cause of our conscious world. A secular controversy, not yet concluded, has been waged as to which of these worlds is the more ' real ' ; for the setting of them over against each other is at once as modern as mathematical physics and as ancient as Greek philosophy. In calling attention, however, to the distinction, it is not with a view to appraising their relative degrees of ' reality.' It is in order to point out that both thought-things and sensed-things do in fact occur in our experience taken as a whole. A perfect mathematical plane triangle when an object of thought, although created by us as the result of a purely mental process, and never encountered in any sensory fashion whatever, is an experience just as much as a seen or felt (and mathematically imperfect) triangle cut out of wood or paper is. Each is referred to ' some thing ' ; but both are experiences, whereas the ' some things ' are not.

Empirical and Exact Sciences.

In the same way as the sciences of Nature, concerning themselves with sensed-things, make a selection from among our experiences, omit many, and abstract from the fact that they *are* experiences of ours, so other sciences, concerning themselves with thought-things, make another selection of experiences, and consider them as if they also were independent of us. The empirical sciences that begin with sensory material work from this towards its explanation on conceptual lines. Those sciences like mathematics, on the other hand, that begin with abstract quantitative concepts, work from these concepts and their relations towards a statement of the implications that are contained within them. The former sciences derive the force of conviction with which they impress us from the fact that they are ultimately based upon the evidence of our senses—'Seeing is believing.' The latter likewise convince us by their proofs, because their conclusions evidently follow from their premisses—'There is no proof like a mathematical proof.' The point to be stressed again, however, is that both these kinds of science are selective of their material and leave out of account much experience which, as such, is as good as any other. If seeing is believing, and mathematical proof convincing, the immediate living experience of myself knowing and feeling and willing is most impressive of all. Though not a Cartesian, in this I agree with Descartes that such experience is not merely believable or convincing, but indubitable. I suggest that these neglected experiences are necessary to explain the constructions of the empirical sciences of Nature, for we need no longer concern ourselves with the deductive sciences. And I further suggest that it is psychology, concerned with the totality of experience, objective and subjective alike, of which we are or may be conscious, and making no abstraction from the fact that it *is* experience, which provides an account of the empirical origin of principles of systematisation and explanatory concepts alike which are used in the other sciences. Though these principles and concepts are abstract, and indeed vary in degrees of abstraction, from qualities and their relations, through quantities and their relations, to being and its relations, in a sort of hierarchical order, they are and must be abstracted from something; and if that something is not the sensory material with which physical science deals, then it must be discovered in some other region of experience. To support this contention it is not necessary to have recourse to innate ideas; for it can be shown that observable mental processes, other than the apprehension of sensory experience, can account for the facts. And these processes are the apprehension and abstraction of relations between any experiences, this term being taken in the broadest sense, the production of correlates in respect of any experience, and the immediate awareness of the self energising, or being in one way or another busy with its objects. I summarise these considerations as follows. All systematic principles and explanatory concepts are in some way derived from experience. They are all mental products, the results of mental processes. They differ in degree of abstraction. Psychology is concerned with the totality of experience as such, and the processes, among others,

by which systematic principles and explanatory concepts come to be formed. And it is the most empirical of all the sciences, since the concepts of which it makes use are drawn directly from within experience itself, or, if inferences from it, are the least remote of all. I shall hope to illustrate this by reference to several of the explanatory concepts actually in use in physical and biological science and in psychology. But before doing this it will be useful to recall and distinguish the several stages by which science proceeds and in which such concepts are reached.

Data of Science.

The first step taken in any empirical science is to examine, describe, and classify the objects, or aspects of objects, with which it deals ; such classification being made on the principle of similarity and difference, which, it may be noted, does not involve inference, but depends upon the immediate experience of relations. The first step in psychology will accordingly be to observe, describe, and classify mental processes as such. Psychologists are fairly well agreed on the broad classification of these processes under the three heads of cognition, affection and conation, or knowing, feeling and willing, as aspects or actualisations of the self. But, though I have used the terms synonymously, I may note that there appears to me to be good evidence that conation (striving and doing) and willing (resolving, intending, choosing) cannot be included in the same general category ; and, accordingly, that there are at least four broadly irreducible kinds of mental event, which will require four groups of concepts to explain them. Classification, however, does not merely mean grouping together : it means separation as well. Thus cognitive processes separate into sensory perception, conception, judgement, reasoning and remembering, for each of which a different explanatory concept may be needed. Though memory, for instance, may be involved in perception, we cannot explain remembering and perceiving in the same way. Incidentally, the postulate of retentivity is a good example of the kind of inference made in psychology. It is evidently an inference, for we do not experience retentivity. But it is not a remote inference ; and does not become so until we further postulate some such thing as persistent brain traces to account for it. Similarly different concepts may be necessary to explain the experiences of desire, resolution, impulse and striving, whether they are classed under two heads or one, and no matter how closely one may be involved in the other.

Structural Analysis.

The next step consists in the finer structural analysis, so far as this is possible, of the phenomenological data. In psychology, this means the further splitting up of the products of mental processes. On analogy with the procedure of the chemist, who analyses a chemical compound into its constituent elements, or of the anatomist, who dissects out the fibres of a nerve trunk, the psychologist analyses a percept, memory, emotion or will-act. The proverbial seen orange yields in such an analysis sensory factors of an elementary kind—colour, odour, sapidity, smoothness, and the like. It cannot be said, however, that these are all

actually seen, any more than the thinghood with which the orange is invested in our thought. Apart from the shape and colour, all the rest comes from other experience than visual. The simplest case of visual perception is illustrated by a coloured figure, in which (except for thinghood) the experience is wholly visual ; and here analysis gives shape and colour as elements. It has been objected that such analysis destroys the mental ' whole ' which is so analysed, just as chemical analysis destroys the compound, or anatomical dissection the preparation ; and this would be still more true did the anatomist separate living structures. He could not, by merely bringing them together again, restore the organism, any more than the chemist, by merely adding his elements together, could recreate the compound. And, indeed, even though we are unable to separate one sensation from another in a percept, and can only distinguish them in our thought, this objection holds good. For, if we think the sensations separately, and then attempt to add them together conceptually, we discover that the mere sum of sensations is not the equivalent of the percept. This objection has been urged particularly against the work of the introspectionist schools, as if they were concerned only to find the mental elements out of which all consciousness was once supposed to be compacted. But introspection has discovered more than the mere sensations that have been distinguished. It has found relations which obtain between the sensations, as well as relations obtaining between abstract concepts, and between concepts and percepts also. This discovery is one of the most fruitful of all the empirical observations of psychology. A similar consideration might be developed in respect of the psychology of volitional processes. The Louvain school, for instance, like that of Würzburg, analyses the elements that enter into processes of resolution and attainment, and of choice. But it would be a mistake to think that these elements, so analysed, when conceptually put together again, are the equivalents of the will-processes. Here also are discovered relations which obtain between them ; and among these is that most important of all real relations, the relation, namely, of cause, which is so closely identifiable with the self. It is in virtue of this relation that a will-act from beginning to end is constituted as a temporal whole. If one keeps in mind the fact that both in spatial and temporal ' wholes ' neither the sensory and volitional elements nor the relations occur in isolation, this procedure of structural analysis is fully justified.

Functional Analysis.

A further step is to discover by functional analysis the conditions or laws of occurrence of the various events with which the science is concerned. In psychology, this has meant in the past the attempt to relate physical stimuli and their intensities with psychological occurrences, as in the case of Weber's Law ; or to relate physiological events with psychological ones, as in the localisation of sensory and motor functions in definite areas of the cortex, or conative and emotional changes with the physiological disturbances indicated by the pneumograph, sphygmograph or psychogalvanometer. The establishing of such relations between physical properties and physiological processes, on the one hand, and

psychological processes, on the other, requires, however, that we shall already have taken a step away from the empirical standpoint in the first sense of the term ; for here we are trying to equate a sensory experience with a thought-object, physical or physiological. My sensory impression of the weight of a loaded can as greater or less than that of a previously lifted can is measured against the ' real ' weights of ' real ' cans as indicated by a balance. But what do I know of ' real ' weights and ' real ' cans ? I have kinæsthetic experiences and can discriminate between them ; I refer these to cans, and call them weights. I have likewise visual experiences of coloured shapes (the balance and cans) altering their spatial relations ; again I refer these to the cans, indeed to the same cans, and say they are due to weight. So far as sensory experience alone goes, I am equating amounts of felt effort with amounts of seen movement, and arguing analogically from one to the other. But how is this possible, since the two sets of experiences are not only different, but absolutely irreducible ? Only, I suggest, because I have conceived something which is contained neither in the experience of effort nor in that of visual movement—namely, a physical can with physical properties affecting me in these ways, a ' same thing ' appearing under two (or more) irreducible forms.[1] But the kinæsthetic experience of weight does not always correspond absolutely with the visual indication ; for the balance can detect differences in weight better than I can, or so I believe. And I believe this, not in virtue of the sensorial experiences alone, but because of even more conceptual construction than has already been indicated. In a similar manner, my experience of conation or emotion is equated with the visual indications of the instruments I am using. I report more or less of ' alertness ' ; I find the galvanometer deflections of greater or less excursion ; and I take these to register more or less physiological disturbance which is correlated with my experience. Again, there is a vast amount of conceptual construction involved in my conclusions.

These conceptual and inferential procedures, however, are thoroughly justified if we admit, as I think we must, that not only sensory experience but all experience must be taken into account ; and then we must concede a like right of citizenship to whatever we are able to discover within it. As we have seen, we find thought-objects as well as sensed-objects and relations both ideal and real. Above all, we find an active self busy with all these mental objects and relations in the various ways of sensing, thinking, feeling, willing, striving, and the like. It is in this complete, unselected experience that we discover the experiential grounds for all our inferences.

Explanatory Concepts.

The last step is to find the least number of suitable explanatory concepts to cover all the data. Like the conditions and laws of occurrence—for indeed they are reached by the same process of functional analysis—these may be physical, physiological or psychological. In point of fact, for the most part those that have been advanced have been physiological—

[1] Incidentally, this difference between sensed-weight and thought-weight is, I believe, an explanation of the size-weight illusion.

special sensory organs, local cortical areas, inhibition centres, association fibres, resistance at synapses, drainage of neural energy, and so on. There can be no doubt that some of these concepts are illuminating for psychology, but again at the price of abandoning the purely empirical standpoint in the first sense of the term, and borrowing from experience other than sensory in order to make explanatory use of them. And indeed the experience from which the loan is taken is precisely that for which no physiological explanatory concepts are available. While we may accept engrams as the physiological reading of retentiveness, association fibres as correlated with the linkages between ideas, and the like, there is no suggestion forthcoming from physiology as to what may be the physiological bases of becoming aware of experience, abstracting relations, producing correlates, the volitional control of mental process, or the intimate and immediate awareness of self. Moreover, some of the physiological concepts in question have in the first instance simply been taken over from psychology, others are yet very speculative and uncertain, while others again, plausible enough in hypothesis, would by most orthodox physiologists themselves be rejected, as, for instance, those of the Gestalt theoricians. Still the very fact that these last have been seriously put forward shows how little definitely ascertained physiological knowledge is as yet of use in explanation of mental events.

In any case, the physiological phenomena, like the physical ones, do not contain the principles of their own explanation within themselves. When we examine the segmentation of a cell under a microscope, we conceive of it as a process going on in an existent, material and unitary thing. Whence do those concepts of existence, matter, unity and thinghood, come ? Certainly not, I suggest, from the observed visual phenomena. When we stimulate the nerve of a nerve-muscle preparation and notice a contraction of the muscle, we conceive of the event as a causal one. Whence did we derive our notion of cause ? Not, again I suggest, from the observed sequence. When we measure the intake and output of a living organism, we do so in terms of energy. From what experience is that concept of energy taken ? Again, not from any one, nor from the sum total of observations involved in the measurements. All these and like beliefs with regard to physiological processes, and in particular in respect of their connection with mental events, are inferences from the phenomena, made in virtue of experiences of another kind. Physiology, accordingly, like physics, is an empirical science in the first sense because it concerns itself with certain selected sensory data ; in so far as it is explanatory, it is an inferential science. It is none the worse for that, however, even if it must borrow some of its concepts from psychology. The point is that, generally without acknowledgment, it does so borrow from psychology in order to establish the very constructions it offers to reloan to that science as explanations of mental events.

Psychology as Science of Experience.

We turn now to psychology, the most empirical of all the sciences in the sense that it deals directly with experience as such, makes no partial selection, but embraces all experiences alike indifferently, and at their

face value. And here I wish to show how scientific explanatory concepts, together with concepts which the physical and biological sciences other than psychology usually reject, are all derived from immediate experience.

Analysis of Concept of Causality.

Perhaps one of the best ways of developing this thesis is to consider first the historical evolution of the notion of causality, which was invoked to account for movement or change in the physical universe. After the two exceedingly significant though somewhat naïve conjectures of love and hatred, and of mind as causal principle in Nature, an analysis was made by Aristotle, as a consequence of which five explanatory concepts were considered necessary to show how any change or movement could come about. There were the two intrinsic principles constituting the thing to be changed. One of these—' matter '—was conceived to be an indeterminate though determinable principle, which endures throughout the process of change and is, before the alteration, specified in its particular mode of being by a determining principle—' form.' Change means that a new form comes to actuate the matter ; and it involves also the negative concept of ' privation,' since before the change the alterable thing is ' deprived ' of the mode of being it will exhibit after the alteration has taken place. Further than this, there are the two concepts of the agent which brings the change about, the ' efficient ' cause extrinsic to the thing changed, and the reason why the agent acts, the end, goal or ' final ' cause, towards the realisation of which the action is directed. Like the earlier attempts, this exceedingly acute analysis of causation, applied as it was to events in the external world, is an entirely anthropomorphic one. It reads into physical phenomena, in a conceptual manner, experiences which are wholly subjective. And this is at once apparent in all the examples that are brought forward to substantiate it. For instance, I, the agent or efficient cause, mould a thing, let us say wax, which is not now a sphere but a cube, into a spherical form, because I wish to have a sphere. Or I hew a formless block of marble into the shape of a statue. These are goal situations, in which an end must be intentionally set up before any action takes place ; something is consciously aimed at, or intended.

De-Anthropomorphisation of Physical Science.

Now, in the course of the development of scientific thought, first the concept of finality was jettisoned as not applicable to events in the physical universe : and certainly, though by analogy we can still apply that concept, derived from our own immediate experience of volitional activity, to the events of Nature, we are unable to discover it within the phenomena themselves by which Nature and its events are displayed to us. In those phenomena alone there is no indication of goal-seeking. The next concept to be dropped was that of efficiency, in the sense that one thing actually produces changes in others. And though, again by analogy, we can apply this concept also to the realities we believe to be sensorially presented to us, efficiency is in fact nowhere to be found in the phenomena. We are left, then, with sequences of antecedent and consequent, conceived

as equivalent in amount of energy. To be sure, temporal sequences, as well as spatial relations, are to be observed in the phenomena themselves, and even similarities that can be *interpreted* as equivalences ; but they do not display energy, any more than teleology or efficiency. Most men of science go no further than this in their rejection of the concepts originally invoked to account for physical causality. That of ' privation,' perhaps because too obvious, is seldom considered ; while ' material ' and ' formal ' principles linger on under other names, such as spatial configuration or arrangement in stereochemistry, or in the physics of the atom. Other men of science, more mathematically and philosophically minded, substitute equations for equivalences, and causal indeterminism for rigid determinism. The history of the successive modifications of the theory of causality, thus briefly and inadequately outlined, is evidence of the de-anthropomorphisation of physical science. At every step, however, in the refinement of the physical concept one fact emerges—namely, that at no point is it possible to dispense with concepts derived from experiences other than those actually to be explained. Aiming at ends, efficient action, energy, equations, are not found in the phenomena in question, any more than thinghood and unity which are necessarily involved in any and every conception of causality. What, then, are those other experiences in which we have the concrete facts from which we abstract the concepts that we apply to the phenomena ?

Origin of Scientific Concepts: Thinghood, Unity.

Beginning with the last concepts named, the notions of ' thing,' ' same thing,' and of ' unity ' are derived, and can only be derived, from the immediate awareness we have of ourselves as unitary, existent and self-identical beings. When I see and handle any object, such as a book, I have visual and tactile impressions which I refer to an extra-mental thing, it matters not what it may be as a physical object. The visual impression, however, is not the tactile one ; and neither, nor both together, is the book. Sensorially, I do not apprehend the book at all, but only ' properties ' of the book. Why, then, do I think that there is a book ? I interpret the phenomena, analogically with my immediate awareness of myself as affected by states, and posit a physical book with physical properties to account for the phenomena. Only later do I refine my notions of physical ' properties,' and conceive them, together with the book, not as like but as very unlike the original sensory data. The kind of mental process that occurs here is even more strikingly illustrated by another consideration. I put the book aside, and busy myself with some other matter. Then I pick it up again, and see and handle it afresh. I believe it to be the same book. But on what grounds ? On the grounds of the similarity of the previous and present phenomena. To apprehend a relation of similarity between phenomena, however, is not to apprehend identity either between the phenomena [2] or between the physical book previously posited and again posited now. There is no sensorial way of apprehending or of establishing identities. What happens is that again

[2] Indeed, as mental occurrences they are absolutely different.

I interpret the similar phenomena, on analogy with my immediate (non-sensorial) experience of self-identity, and posit a selfsame physical book enduring in time. Finally, my notion of unity also is derived from the same source of immediate, non-sensorial experience of myself, and analogically applied to sensed-things and thought-things alike.

Origin of Scientific Concepts: Energy.

Passing next to the explanatory concept of energy, still in general use in the sciences of Nature, we find that this also is not to be discovered among the particular selected sensory phenomena with which they deal. This concept of physical energy, kinetic and potential, refers to a postulated persistent entity (' same thing '), constant in amount, which may be transformed from one state to another, and is capable of doing work in bringing about physical movements. To what source in experience can we trace this notion? Clearly it is not sensorially apprehended in the physical phenomena observed. It might at first sight seem that it should be traced to kinæsthetic experience, or the sense of effort in bodily activity by which different kinds of work are done; that we read this analogically into the physical phenomena, and project the result into a ' physical ' world. But I do not think that this can be a true explanation, for the reason that, like the properties of the book just considered, the sense of effort, experienced in one case, is only similar to the sense of effort experienced in another. It can in no sensory way be shown that they are identical. Likewise, the body, in the same way as the book, in any successive pulses of sensorial apprehension, displays no more than a relation of likeness. Accordingly, I appeal again to my immediate non-sensorial experience of self-identity, in which I discover an active self energising in one way or another. It is true I do not find any perpetual and unbroken continuity of self-consciousness; but, whenever I am conscious, notwithstanding all the changes that take place in the phenomenal world, including those of my own body, I am conscious of the same unitary and self-identical I. Now, can we find the basis of the concept of energy here? I maintain that we can, in the sense that this self does actualise, or energise, in different ways, now perceiving, now judging, now resolving, now enjoying, and the like. And from this I infer, though the inference is by no means a remote one, that a self which does all these things can do any one of them, even if it is not actually doing that one at the moment. Here I find, in immediate living experience, the source from which the abstract concepts of energy and dynamism are drawn; and these concepts, applied to the phenomena of motion or change, become those of kinetic and potential energy, and are projected upon an extra-mental world of things which we have conceived on analogy with ourselves.

Validity of Scientific Concepts.

There are no doubt other lines of approach to the development of the thesis I am maintaining than the one I have taken; but I have chosen this because it most readily allows me to stress the point I wish to make. If we begin with the principles and postulates of which the different sciences

make use in systematising and explaining their selected data, without a previous examination of their source of origin, just taking them for granted or as obvious, we are extremely likely to give them precedence over all others, and to suppose that they possess a greater validity than others, or even that they alone are valid. In this way, it would seem that commonly accepted principles of physical science, such as those of determinism or the conservation of energy, have come to be regarded not only as of supreme validity in physics, but even as strictly applicable also to psychological events, including those from which, by way of conceptual construction, they have been derived. I am here in no way trying to argue that these principles and postulates are not true. There may be a universe of physical objects, in which energy is conserved, and all events rigidly determined. What I am arguing is that these thought-things are inferential constructions from sensory phenomena, which are possible only because of experiences other than sensory and phenomenal, and that they must not be permitted to displace or contradict those very experiences in virtue of which they are built up. If we had worked backwards in the history of the evolution of the notion of causality, instead of forwards as we have done, we should have found that we were leaving the region of remote inference for that of proximate inference, and this again for that of experience pure and simple, until at last we reach the immediate experience of the self as actively engaged with its mental objects. We should have reached then the central core, so to speak, of all experience. And here we find, not merely a concept nor a phenomenon, but an actual thing, or active substance existing in itself, from which the notions of thinghood, substance and activity are abstracted ; we find here an efficient cause actually producing its effects, such as remembering a forgotten event or altering the character of phenomena by willing to do so, and from this the concept of efficiency is derived ; we find a substantial cause in multiform relations with sensed-things and thought-things, among which is the goal relation, whence the idea of finality or teleology arises.

Psychological Processes of Concept Formation.

From such experiences as these, to which we apply relations likewise experienced, we derive the proximate inferences such as those of retentiveness or mental energy, to which allusion has already been made. From them also, as well as from our immediate experiences of the apprehension of relations and the production of correlates, we infer the proximate principles of noetic eduction. And, lastly, from them again, by further applications of relations to them, to phenomena, and to correlates already produced in our thought, we reach the far more remote inferences of which use is made in the sciences of Nature ; for here we refer our experiences to transexperiential, extra-mental causes. But the grandiose system of the natural sciences as a whole stands in virtue of these original experiences ; and it would crumble away into less than dust did they not guarantee it.

It is for this reason, provided the meaning of the term be not limited to sensory experience only, but be extended to all and everything that may

be experienced, that I maintain that psychology is the most empirical of all the sciences.

Perhaps I may end with another quotation from the writings of the same distinguished physicist from whom I quoted as a text: ‘ We have found a strange footprint on the shores of the unknown. We have devised profound theories, one after another, to account for its origin. At last, we have succeeded in reconstructing the creature that made the footprint. And lo ! it is our own.’

THE TYPES OF ENTRANCE MECHANISMS OF THE TRAPS OF UTRICULARIA (INCLUDING POLYPOMPHOLYX)

ADDRESS BY

PROF. FRANCIS ERNEST LLOYD, M.A., D.Sc.,

PRESIDENT OF THE SECTION.

It is an honour greatly appreciated and wholly unexpected to have been selected to preside over your Section of Botany on this occasion, the Leicester Meeting of the British Association for the Advancement of Science. To express my feelings in any plenary sense would take too much of your time, better spent on the subject before us. I therefore offer you my best thanks for your confidence. If the subject which I have chosen is one as full of interest as it is devoid of practical importance (so far as we can at present see), I may plead that I am following the example of your illustrious Hooker, whose address at the Belfast Meeting in 1874 was in the same field and equally open to the criticism.

This subject [1] has the purpose of setting before you the variety and, so far as I have compassed them, the minutiæ of structure and behaviour of the door, or valve (as Darwin called it), and its contactual parts, particularly the threshold, of some 75 species of the genus *Utricularia*. Such a number out of the whole of some 250 known species may be taken as sufficiently representative to allow us to obtain a fair picture of the lot. That I have been able to examine this fairly adequate series has been due to the helpfulness of correspondents in various parts of the world, acknowledgments of which I have already made elsewhere. It must, however, be added that the study of preserved material to any good purpose would not have been possible without the foundation work of studying such living material as has been available, including the following species: *U. vulgaris*, *U. intermedia*, *U. gibba*, *U. emarginata*, *U. capensis*, *U. reniformis*, *U. cornuta*, *U. longifolia*, *U. cœrulea*, etc. In this connection I should not fail to add that I have had the able co-operation of Mrs. E. R. Johnson, *née* Reed, of Perth, Western Australia, and of Mr. Allan McIntyre and Mr. A. V. Giblin, of Hobart, Tasmania, in carrying out

[1] The present paper may be considered a continuation of my presidential address, entitled 'The Carnivorous Plants—A Review with Contributions,' delivered at the recent meeting of the Royal Society of Canada, May 18–20, 1933. A motion picture showing the action of *Drosera* and of *Dionæa*, exhibited on that occasion, is shown as part of the motion pictures as completed especially for this.

certain critical observations, which enable me to say with conviction things relating to Australasian species which otherwise had not been available in the living form and whose peculiarities well-nigh defied analysis. I refer to *U. dichotoma* and related species, and to *Polypompholyx*.

The species of *Utricularia* (I include *Polypompholyx* for the purpose of description from now on) fall into two major ecological groups: the submersed, floating forms, of which the familiar *U. vulgaris* and less familiar *U. purpurea* are good examples, and the so-called terrestrial forms, of which the frequently cultivated *U. reniformis* and *U. cœrulea* may serve as illustrations. This statement leads me to emphasise the fact that the structure of the bladders, or traps (as I prefer to call them), is far more uniform, almost to monotony, within the submersed forms, while the contrary is true of the terrestrial. That this should be the case seems natural, as the environment of the submersed kinds is more uniform. But that the diversity of the remainder should be due to the lack of uniformity of environment is not so clear, since the lack is, I imagine, more apparent than real. The terrestrial species are all confined to a very wet substratum, and grow usually as much submersed as the floating forms; and the species which appear to be the least limited in their need of water are those which, like *U. reniformis*, *U. longifolia*, etc., grow in wet moss as epiphytes, etc., and in spite of this are most like the submersed *U. vulgaris* or *U. gibba*. Whatever the explanation, it is my present purpose rather to display the variety of the traps and to attempt to explain their workings.

In order to approach immediately to this purpose I shall clear the way by summarising those properties which are common to all.

1. *Nature of Action.*—The trap is a snap-action mechanism—that is, it acts with extreme suddenness, much to the surprise of Darwin when he examined *U. vulgaris*.[2] So swift is it that the whole action falls within the limits of $\frac{1}{16}$ second, and by means of superspeed cinephotomicrography, taking 160 pictures a second, I have found that the opening phase of the door falls within $\frac{1}{160}$ second, while the closing phase is completed in four pictures, or $\frac{1}{40}$ second. All the species which I have examined act similarly. During this brief moment the side walls of the trap spring out, the shape of the periphery as seen in lateral view alters correspondingly, the door opens fully and closes, falling into a semi-relaxed position, during which a column of water, carrying with it any luckless animals if small enough, rushes into the interior of the trap. The closing movement of the door shuts off the water before the walls have completely relaxed, so that, on closure being completed, there remains still some degree of ‘ negative ’ pressure. As Merl (1922) showed, complete relaxation may be procured experimentally, either by puncturing a wall of the trap or by holding the door open for a moment, thus throwing it out of action. I have shown also that cutting the velum has the same result.

[2] The action of the trap in *U. vulgaris, U. gibba* and *U. purpurea* is demonstrated by means of motion pictures. By means of animated diagrams the particulars of behaviour of the door are shown for *U. gibba, U. vulgaris, U. cornuta* and *U. cœrulea.* The rate of movement of the door of *U. vulgaris* is demonstrated with superspeed motion picture taken at the rate of 160 frames per second. The question of irritability has been dealt with by me elsewhere (1932).

2. *Resetting.*—After discharge the trap resets itself after a period of from 15 to 30 minutes or more, in *U. vulgaris*, or as long as 2 hours, more or less, in *U. purpurea*. In this operation water leaves the interior of the trap by diffusion through the walls, until an equilibrium has been reached and the walls have become concave so much as to press tightly on each other (in *U. purpurea*), or at least to be closely approximated (*U. vulgaris*, *U. gibba*, *U. cornuta*). In other words, the trap acts as a cell when surrounded by a slightly hypertonic solution of a sugar or salt if harmless; but in the case of the trap this condition is not necessary, though with sufficiently high solutions of sugar, etc., within, the trap will take up water rather than lose it. Czaja (1924) has studied this aspect of the physiology of the trap, and tells us that the walls are semi-permeable, allowing water to pass but not solutes, but evidently this is not the whole explanation. For our present purpose we need not discuss this problem, merely recognising the fact that water passes out from the interior of the trap, thus producing a reduced pressure within. As a result, the outer water presses equally everywhere—on walls and door alike. When, therefore, the door is shifted out of its position of equal resistance, the water pressing thereon pushes the door in. Thus is furnished a part of the energy required to actuate the trap. The remainder (an amount not measurable, or at least not yet measured) is supplied by the tensions of the (living) walls themselves, which, with an even water pressure within and without, still always take on an extreme convexity, when the trap can be said to be completely relaxed. From this condition a sound, undamaged trap will reset itself in a period considerably longer than that required after normal actuation when it is only partially relaxed.

The energy required for the actuation of the trap is derived from the water pressure plus the outward spring of the walls. From now on, this will be understood and no further reference made to it.

3. *Watertightness.*—Since the above is always true, it must also be that the door is watertight.[3] I have shown (1929) that this watertightness is owing to the presence of a membrane, the velum (Figs. 21–25), which arises as a cuticular development from the pavement epithelium of the threshold, though in certain species other regions contribute to produce an accessory velum (Fig. 15), as we shall see. All the living species examined conform to these statements. How the door is engaged when the trap is in unstable equilibrium is a particular question, along with others, as to the extent and proportions of the threshold, origin and extent of the velum, and the method of actuation. These points, therefore, are to be considered specifically in what follows. There is, however, one underlying fact which may be mentioned at once in this connection—namely, that the free edge of the door is always longer than the threshold at its inner angles (Fig. 23). The latter can be readily understood when the development of the trap is considered and, as Meierhofer (1920) has cleared this up, it is not necessary to further amplify. It follows that the door edge cannot lie smoothly along the surface of the threshold when

[3] When the adjective 'watertight' is used, I imagine that it must not be taken too literally. As long as the inleakage is at a lower rate than the outward diffusion through the walls, the trap will work.

it is parallel with a component thereof; or, conversely, if it does lie smoothly, it is always oblique to the threshold. If, as in the former case, the edge is parallel to the threshold, there must be a region where, when the door is opened, it buckles. In the normal action of the door the point of buckling, which is necessary to its opening at all, is structurally predetermined as to its position. How in particular this is accomplished will further appear.

4. *Histology of the Door.*—The tissues of the door are of two kinds (always of two courses of cells), hinge and middle piece. The former occupies a zone around the sides of the door, the latter a more or less extensive area at the middle of the lower edge and extending upward from this to some distance. Hinge tissue has a course of deep cells backed by a thin course (Figs. 3–8). It is extremely flexible, and can bend sharply through an arc of 180 degrees without damage. This results, in large part at least, from the character of the deep cells, whose periclinal walls, inner and outer, are in the form of bellows. The anticlinal walls of both courses are reinforced by numerous cellulose props which prevent collapse on bending (Lloyd, 1932). In the middle piece the two courses of cells are of equal thickness, and while flexible the tissue has a certain rigidity and resists flexure in both directions equally. The walls are very richly provided with cellulose props. The function of the hinge is to keep the door flexed outwardly as far as possible. If this outward stress is met by the threshold, the effect of the hinge is to exert a thrust of the middle piece against the resisting surface (*cornuta* type). Aside from the above, each type of trap requires special treatment.

5. *Trichomes.*—In all species there are glandular trichomes on both the outer and inner surfaces of the trap. Those on the outer surface are usually sessile, of three cells (basal, mid- and capital cell—the last often doubled), the pattern of structure of all the glandular cells wherever occurring. These are found scattered over the whole plant surface, and are not peculiar to the traps, on whose interior surfaces occur trichomes of similar basic structure, but the outer two to four cells forming the capital are elongated or, if with a single-celled capital, there is a single sausage-shaped terminal or capital cell. Some species, therefore, have quadrifid and bifid trichomes (as Darwin called them) devoid of cuticle, the latter in the vicinity of the threshold; or bifid and single trichomes, correspondingly placed. They may be few or very numerous, e.g. in *U. longiciliata* but six; in *U. lateriflora*, sixteen; in *U. vulgaris*, hundreds. The form is very characteristic, but familiar to anyone who has only cursorily examined the interior surface of the trap of any species.

The distribution of these trichomes is various. There is always a segregation of single and bifid, or only bifid trichomes: (*a*) on the inner surface of the threshold bolster, (*b*) on the surface above the inner margin of the threshold, and (*c*) on the general surface of the interior, which may be very thickly studded everywhere, or may be many fewer and placed in rather definite positions, e.g. they are frequently absent from the flanks and confined to the more peripheral, especially ventral region, as viewed laterally. What these differences may mean is obscure; I am inclined to regard such as of no importance whatever.

6. *Appendages.*—The trap is usually provided with appendages, though there are a few exceptions, e.g. *U. cornuta* (Fig. 1), *U. nana.* In the submersed, floating, or semi-terrestrial forms resembling *U. vulgaris*, there are two antennæ which are more or less fringed with long bristles, and similar bristles radiate from the sides and top edge of the entrance, but these may be almost entirely absent. Or, instead of antennæ, there may be two (*U. lateriflora*, Fig. 13) to about seventeen (*U. Kirkii*) rows of bristling trichomes, forming a funnel-shaped lead to the entrance, which may also be provided with a proboscis projecting from the upper (*U. albina*) or from the lower lip of the entrance (*U. longiciliata*) ; or the latter may occur in the absence of any other appendages (*U. elephas*). On the surface of it, these appendages have been interpreted as guides to the entrance, but in many instances it is difficult to regard them as of any importance whatever. For our present purpose these may be disregarded, except as they may have some bearing on the character of the entrance.

In order to avoid confusion arising out of the great mass of material, I shall choose types of various groups for special consideration.

The Type U. cornuta (Figs. 1–8).

I begin with *U. cornuta* because it is the simplest in structure, though not by this token a primitive form. Schimper published in 1882 a description which was wrong in most particulars, so far as the structure of the door and threshold are concerned. My own account (1931), brief and very incomplete as it was, was offered before I had had the advantage of studying living material, and it is wrong in regarding the relaxed position of the door in the set position. I can now make amends for my inaccuracies.

The trap in lateral view is rounded with a protruding beak beneath which is the entrance, and a stalk. The large traps are about 1 mm. in diameter (Fig. 1). Viewed on edge, the sides are seen to be concave when the trap is in the set condition, and convex after actuation. Owing to the approximation of the stalk and beak, an edge view, showing the stalk, does not display the entrance proper, but this I have shown in another figure (Fig. 2). In this we see that the entrance is bounded by a lower lip in the form of an inverted arch, not quite circular. Above the edge of the lip we see some irregular cells projecting radially. These are the forward courses of cells of the pavement epithelium. Hanging downward from the beak and extending inward is the door. This figure is a thick section, beginning at *f*, and extending as far back as, say, *d*, Fig. 3. By consulting this latter figure one sees that the arched entrance leads to a curved platform (approximately semi-cylindrical) lined with the pavement epithelium, made up of glandular cells of elongate form, being the capital cells of a closely packed tissue of glandular trichomes. Schimper recognised these trichomes as being of structure similar to the glands of the outer surface, as also did Goebel, Hovelacque and others for other species. But, hitherto, students have supposed that the pavement epithelium is uniform in structure, which indeed, when regarded superficially, it seems to be. If we dissect away the adjacent parts, so as to

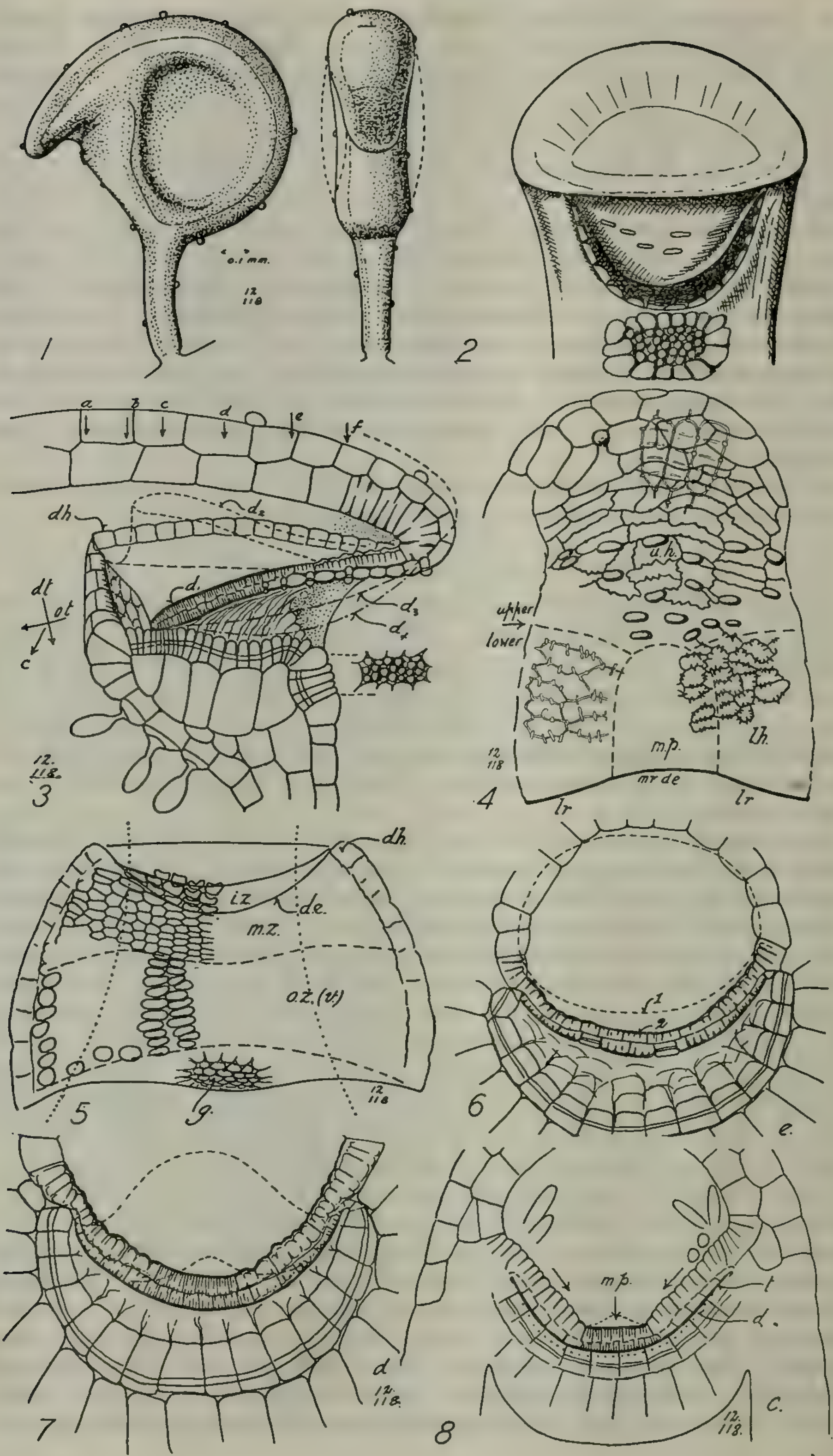
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PLATE I—References.

Figs. 1–8. *Utricularia cornuta.* Side and front view of the trap. The broken lines indicate the set and relaxed conditions.

Fig. 2. Front view of the entrance.

Fig. 3. Sagittal section of the entrance showing the relations of door and threshold. d_1, door in the set position ; d_2, door in the open position ; d_3, door in the normally relaxed position ; d_4, door when fully relaxed ; *d.h.*, door hinge ; *d.t.*, downward thrust of the lateral hinge ; *o.t.*, direction of thrust of the door exerted by the overhang ; and the resultant thrust (*c*) when the trap is set. On the right the lure gland.

Fig. 4. View of the door as from beneath. *m.p.*, middle piece ; *l.h.*, lateral hinge ; *u.h.*, upper hinge. Cells in lighter outline are those of the inner course. *m.r.d.e.*, middle reach of the door edge ; *l.r.*, lateral reaches.

Fig. 5. Threshold. *i.z.*, inner zone ; *m.z.*, middle zone ; *o.z.* (*v.*), outer zone which bears the velum ; *d.h.*, door hinge ; *g.*, gland which may act as a lure.

Fig. 6. Transverse section of door and adjacent structures : (1) in the set position ; (2) relaxed after actuation. This section is approximately one through arrow *e*, Fig. 3.

Fig. 7. Transverse section (arrow *d*, Fig. 3) of the door through the upper region of the middle piece. The broken lines indicate position taken when the door is opening.

Fig. 8. Transverse section of the door near the free edge (arrow *c*, Fig. 3). *t.*, the heavy line indicates the inner edge of the threshold ; *d.*, dotted line indicates the lower surface of the door edge. The two oblique arrows indicate the direction of thrust of the lateral hinges on the middle piece (*m.p.*). When the door is opened the middle piece bends along the sagittal line.

free the threshold, and carefully spread it (which unavoidably tears it, spreading the cells a little, but not enough to disturb our observations), we may recognise three transverse zones, which I designate the outer (*o.z.*), middle (*m.z.*) and inner (*i.z.*) zones, delimited in Fig. 5. These zones can be identified with those in Fig. 3, where the threshold is cut sagittally. The component cells having the same fundamental structure throughout, we find that those of the outer zone are loosely packed and that their cuticles are raised up to form a great mass of loose membranes, the velum, which, when the door is closed and the trap set, renders the door watertight. The middle zone cells, on the other hand, are smaller and tightly packed (their outlines, therefore, angular), and their exposed faces are flat. This zone is narrowest at the middle and spreads out fan-wise toward the lateral limits of the zone, which furnishes a smooth, firm surface against which the face and edge of the door can press when the trap is set. The inner zone is narrow and lunate, composed of loosely packed cells, with more or less irregular contour. Their general surface is slightly uptilted toward the outside of the trap. The back edge of the threshold is in the form of a roll of tissue, tapering toward the ends. I once thought that this furnished a resistant face against which the door edge rests, but I was mistaken (1931). This point was finally settled by photographing the door and threshold through the wall of the trap while in the living, set condition—optically a rather difficult task.

The door extends from the end of the beak inwardly, is nearly twice as long as broad, and contracted at one point (Fig. 4). This point coincides approximately with the forward end of the threshold, along the lateral margins of which the sides of the door are attached to the wall (*d.h.*, Fig. 3). The extreme ends of the free door edge coincide with the inner angles of the threshold, while its edge coincides, when the trap is set, with the inner border of the middle zone of the threshold. The histology of the door, which is composed of two cell courses, is very important if we are to understand its effectiveness. The mapping shown in Fig. 4 indicates four regions. The outer two-thirds, articulating with the wall of the trap in the beak, is of cells which have their longer axes transverse in the outer course and longitudinal in the inner. All these cells have their radial walls strengthened by cellulose props, but these are much more numerous and larger in the walls of the inner course of cells. Both anticlinal walls of these latter are folded, bellows-like. The inner course, as thus constituted, is capable of much expansion and compression. Their own proper tendency is to expand, so that a freed door bends sharply outwardly. They can bend inwardly in response to pressure on the door, however, so that at once they keep the door pressed on the threshold, but can be bent inwardly when the door is opened by the pressure of water, only to spring the door back into position when that pressure is released. Among the outer course cells there is a number of gland cells, with oval capitals, which may act as a lure (Figs. 3, 4, 6), together with the special oval gland just below the lip of the entrance (Fig. 2). The side walls of the door are constituted quite as the forward region above described. They (Fig. 4, *l.h.*) press firmly in lying in contact with the sides of the threshold (*m.z.*, Fig. 5) and exert a downward

thrust on the middle piece of the door (*m.z.*, Fig. 8), which has quite a different structure, in that the two courses are of equal depth, the cells small and very densely studded with cellulose props, which appear, in the face view of the cells, as more or less regular transverse bands. These have the same function as elsewhere, but here are more numerous, because of the severe flexing which the middle piece is subjected to during initial opening of the door. The properties of the middle piece are stiffness and capacity of flexure in either sense.[4] When the door is closed, the middle piece is held firmly against the middle reach of the middle zone of the threshold (*l.h.*, Fig. 5) by the downwardly thrusting lateral hinges (Fig. 8).

In addition to the door proper, the beak wall cells also take part in the flexures of the door, and further exert a longitudinal thrust on the door, so that this is pushed backward and downward. The thrust of the door edge is then in the direction indicated by arrow *c*, Fig. 3, and is downward against the threshold middle zone. The thrust exerted by the beak is referable to the total flexures of the trap when exhausted ; when the trap has been sprung and is relaxed, the beak is not bent downward so sharply (d_3, Fig. 3).

By making photographic silhouettes of traps in the set, relaxed, and totally relaxed conditions, the difference in shape of the curvatures can be recorded. It has thus been possible to record the position of the door under these conditions. In the set condition the door, as betrayed by the longitudinal aspect, is bowed upward, and the transverse curvature at *e* and *f*, Fig. 3, will be flatter (Fig. 6). This has the effect of a more directly downward thrust of the door edge. After actuation the silhouette of the door is as shown by the broken line d_3, Fig. 3 ; the beak being less bent and the thrust due to the beak being eliminated. If total relaxation is obtained (as by puncturing the wall of the trap), the door takes the position d_4—the dot-and-dash line in Fig. 3. These contours of relaxation serve to emphasise the significance of the curvatures seen in the set condition, when the lateral areas (*l.h.*, Fig. 4) clamp the middle piece firmly on the threshold (Fig. 8), and the upper region of the door is under transverse tension, bowing the door longitudinally. The chink between the door and threshold is now filled with the membranes of the velum, making the whole watertight.

Actuation is procured experimentally by slight pressure of a needle point (the operation must be without damage to the tissues) on the surface of the door in the region *e–f*, Fig. 3. Sometimes a very light touch will do the trick, but I get the impression that the mechanism is not so sensitive as that of *U. purpurea* or *U. vulgaris*. The smallness of the trap makes experimentation difficult. What happens in nature can only be inferred. It is to be noticed that there is a total lack of appendages supposed to act as guides and lures, the only equivalent being the gland below the entrance and the glandular trichomes on the door surface, aggregated chiefly in the region of actuation. But it is not difficult to make the inference that a small animal (Schimper mentions rotifers, worms and

[4] For a full discussion of the histology of the door, see my paper of 1932 in the *Canadian Journal of Research*.

crustaceans, and I have seen the same or similar forms), crawling about the entrance, could enter far enough to touch and press inwardly, slightly denting the surface of the door in that region. This would upset the unstable equilibrium and the pressure of water would take advantage of the initial flexure, which would then travel toward the door edge at the middle of the middle piece (Fig. 7). This, in turn, would nullify the lateral thrusts of the sides of the door, and the water pressure would, folding up the sides, open the door (Fig. 3). To be noticed is the fact that the structure of the door in the region of actuation is such that it would give readily to local pressure, though the distributed water pressure would be resisted (Fig. 6).

In summarising the case before us, we note that the threshold is broad (ratio of breadth to length, 2 : 1 approximately) ; that the door is long and narrow and has no special tripping mechanism, an initial dent being sufficient to upset the unstable equilibrium ; and that the velum is very broad. The door is held in tight application to the threshold by the thick lateral regions, these exerting a downward thrust on the middle piece, which can bend longitudinally. The end of the beak also contributes to the door mechanism, and has inner course cells which are strengthened by props. Although simple in appearance, the door mechanism is elaborately endowed with suitable curvatures and cellular structures which make its behaviour possible. It is a snap-action mechanism, as determined by much careful observation.

U. cornuta is a New World type, and the few species have the identical trap structure. A species (my No. 43) from the Aripo Savannah, Trinidad, collected in fluid by Professor R. B. Thomson in 1931, with spatulate leaves (thereby distinguishing it from *U. cornuta* with linear leaves), and *U. juncea* (Vahl) Barnh., collected by De la Cruz, 1543, in British Guiana (my No. 108) and by Britton and Britton (29) in Porto Rico (my No. 110), are the only other species I know. Of *U. juncea* I have seen only herbarium material.

The Type U. capensis (Fig. 20).

I choose for the next type *U. capensis*, which I had the opportunity to study in the living condition on the occasion of the meeting of the British Association at Cape Town in 1929. For the use of the laboratory and facilities I am indebted to Miss E. L. Stephens, who has continued to help me in various ways. The reason for the choice of this type is the similarity in the general proportions and curvatures of the mechanism we are considering to those of *U. cornuta*, though it differs in having no beak, in the sense we have used the term for that species, nor is the posture of the door quite the same.

The trap (1 mm. long) has a thick, and in front, surrounding the entrance, massive structure. It is one with a considerable number of species in which the front is provided with a number of radiating rows of long trichomes, graduated in size, forming guides to the entrance, as we may suppose. These trichomes are glandular and have the typical three-celled structure, the basal cell being much enlarged and often subdivided. The number and arrangement are such as to lend to the trap

a rather horrific appearance. Above the entrance the massive wall protrudes as an overhang, and from the under side of this the door rises abruptly and not, as in *U. cornuta*, as an extension of the wall ; and we have no reason for supposing that the overhang in *U. capensis* contributes to the action of the door, as in *U. cornuta*, in raising the angular divergence with the threshold, contributing to the thrust of the door edge. To compensate for this the inner zone region of the threshold has an upward slope, thus offering a resistant surface of sufficient angle to afford a resting-place for the door edge, while in the door itself there is a set transverse bend above the middle piece.

The door, viewed as a flat object, has a rounded upper region, which is, as seen in the longitudinal sagittal section, relatively thin, with a much thinner outer course of cells than inner in its upper half and the reverse in its lower half. This is correlated with the set transverse flexure, the effect of which is to tilt the lower half of the door (the middle piece) with respect to the threshold, enlarging the angle of divergence. The lower region is differentiated into a large middle piece, whose cell courses are of nearly equal thickness, with thicker lateral regions having the same structure as the upper hinge region, i.e. thin outer course and thick inner course cells. As in *U. cornuta*, the lateral regions exert a thrust on the middle piece. Other features peculiar to *U. capensis* are, first, a tuft of rather large, clavate glands arising from the door upper region and, second, arising from the middle point of the upper limit of the middle piece, a single, curiously shaped, glandular trichome, which I have called the kriss trichome, as well describing the shape of the terminal cell. Its stalk (basal cell) is curved gracefully backward ; the mid-cell is short and oblique, holding the terminal cell in a backward-reaching position between the middle piece and the threshold. If this structure has any function, we do not know what it is. The absence of cuticle from the terminal cell suggests that, in common with the glandular trichomes, mucilage is excreted, but this does not throw light on the peculiar form, nor does it help us to know that in another species, *U. puberula* (New World), the door and general structure are similar in every detail but the absence of the kriss trichome, there being substituted therefor a pair of large, sessile, globular gland (capital) cells. Another species (Old World), *U. Welwitschii*, has, like *U. capensis*, a kriss cell, but it is more sharply curved, scimitar fashion.

The actuation of the trap seems to be initiated by the contact of the prey with the short trichomes on the upper convex portion of the door surface. As in *U. cornuta*, the initial flexure thus caused is transmitted longitudinally to the middle piece, which, flexing along its midline, releases itself from the thrust of the lateral hinges and so the door opens before the moving water column.

Almost identical in structure, as far as the entrance mechanism is concerned, is a group of species, the members of which have an elaborate guide complex ; but here the radiating rows of glandular trichomes arise from a funnel-form elaboration of the front of the trap, while the upper sector of this funnel is drawn out into a long rostrum, as first described by Goebel (1891). The species, as far as known to me, are

U. albina, *U. nivea*, *U. rosea* and *U. Warburgii*, the last two having been described in general terms by Goebel. Three other collections, sent me by Mr. N. D. Simpson (his Nos. 9579, 9857, 9871) from Ceylon, though possibly differing specifically or varietally, have the same general structure. They are all Indian (with Ceylon) and found nowhere else, so far as known. In all these the glandular armature of the door is as in *U. capensis*, except for the absence of the kriss or other similarly placed trichome. The mechanics of the door and threshold are doubtless the same.

Another small group of species (only two, so far as known) of minute plants with the habit of *U. capensis* harmonises with the above in regard to the entrance structures. The one is a Tasmanian, *U. lateriflora*, briefly and inadequately described by Kamienski, the other a Ceylonese species (Figs. 13, 14), collected by Mr. N. D. Simpson (9482) and sent to me (my No. 131). It seems to be undescribed. My *lateriflora* material has two derivations : one lot transmitted by Dr. Merl, but collected long ago by Rodway in Tasmania (my No. 85) ; the other, a well-preserved lot from Mr. Allan McIntyre, of Hobart (my No. 157).

U. lateriflora has a very small trap (including the proboscis, 0·65 mm. long—a large one) with a huge conical downward-turned proboscis and with two short rows of glandular trichomes extending outward and obliquely downward from the lower angles of the entrance, increasing in size, the smallest at the entrance. They thus form two oblique shelves leading to the entrance, which is blocked in front by the proboscis. The capital cells of these trichomes are globose. The door is quite like that of *cornuta*, but the armature of sessile glands is aggregated into a patch on the convex surface of the upper part. The articulation of the door with the wall is, however, like that in *U. capensis*. The external glands are sessile globose.

The Ceylon plant (Figs. 13, 14) has a trap which, at a casual glance, is quite similar to the foregoing. It has, however, a second pair of rows of protuberances on each side and above the level of the entrance opening, but these are not glandular (Fig. 13). The basal cells of the other rows of trichomes are double-celled. The proboscis is smaller and may project straight forward or be more or less bent downward—in this there is no constancy. The threshold is composed of fewer and relatively larger cells, but is clearly zonate, the outer, middle and inner zone being readily recognisable. The glands of the outer surface have elongated capital cells.

On the interior surface of the trap there are single, bifid and quadrifid absorbing trichomes, but these are very few in number and relatively large. In *U. lateriflora* there are fourteen bifids in five rows on the inner flank of the threshold ; six quadrifids above the inner entrance, three on each side ; and two to six quadrifids in the interior, making about twenty-six in all.

The Type U. cœrulea (Figs. 9, 11, 12).

The mechanical principles prevailing in all the foregoing prevail also in a number of species, of which *U. cœrulea* may be taken as a type.

Because of this, my raising *U. cœrulea* to separate dignity has a secondary purpose, namely, to point out that the general form of the trap assimilates it to the trap of the type under which *U. reniformis*, *U. vulgaris*, etc., may be subsumed. A mere examination of the form of the trap would readily lead one to suppose that *U. cœrulea* and *U. reniformis* are alike. The former has single and bifid absorbing trichomes, the latter quadrifid.

The trap in *U. cœrulea* is rounded in lateral view, and the slightly protruding curved overhang is provided with two rather long, curved antennæ. The threshold is broad and its inner region is uptilted, in some species in a marked degree. In sagittal section, the curvatures of the threshold are singularly graceful. The door, also as seen in sagittal section, curves downward and backward, the edge resting on the middle zone of the threshold, in front of the uptilted inner zone. The upper outer surface of the door is beset with a good number of clavate trichomes, somewhat longer above than below, and differing only slightly in form from those of *U. capensis*, etc., and doubtless serving the same function—probably contributing to the attraction of prey or facilitating the actuation of the trap, which, without doubt, consists in causing an initial dent in the upper region of the door, the pressure of water taking advantage of the failure of resistance thus started. In structure, the upper part of the door has a thin outer course and a thick inner course of cells, the same structure extending round the sides as far as the door edge. This is the outer hinge area. The middle piece is thicker and is of cell courses of equal thickness, with thick outer walls. This is compressed downward on the threshold by the lateral hinge areas, as in *U. cornuta*.

Plants with traps of this type seem to be confined to the Old World. They range from very small delicate plants to rather large ones—e.g. *U. equiseticaulis* Blatter and McCann has leaves up to 9 cm. long ; *U. prehensilis* has long twining scapes bearing its yellow flowers. They are all ‘ terrestrial,’ the typical habitat being wet, often muddy, places, the plants forming dense green mats. The leaves scarcely rise above the surface ; when large they lie on the mud, the under surface of the leaves bearing traps, often plugged full of the fine sediment and rendered incapable of action.

Of the species fitting the type *U. cœrulea*, there are known to me *U. Gibbsiæ*, *U. albo-cœrulea*, *U. affinis*, *U. uliginosa*, *U. bifida* and *U. reticulata*, several Ceylonese species only tentatively named (Simpson 9484, 9487, 9492, 9517, 9580, 9581, 9856, 9971, 9972) kindly sent me by Mr. Simpson. I am further indebted to Mr. R. E. Holttum, Mr. T. Ekambaram, and Mr. E. Blatter for Malayan and Indian collections. The structure of the door is much as in *U. cornuta*, being as follows: the upper half and lateral hinges are composed of a thin outer and thicker inner course of cells, the whole effecting outward bending but capable of inward swing ; and, surrounded by the lateral areas, is the middle piece, appearing as the lower half of the door in sagittal section. It is thicker and more rigid and is of cell courses of equal thickness and with thick outer walls (*cf.* Figs. 6–8).

The pressures inherent in the door itself become apparent when a

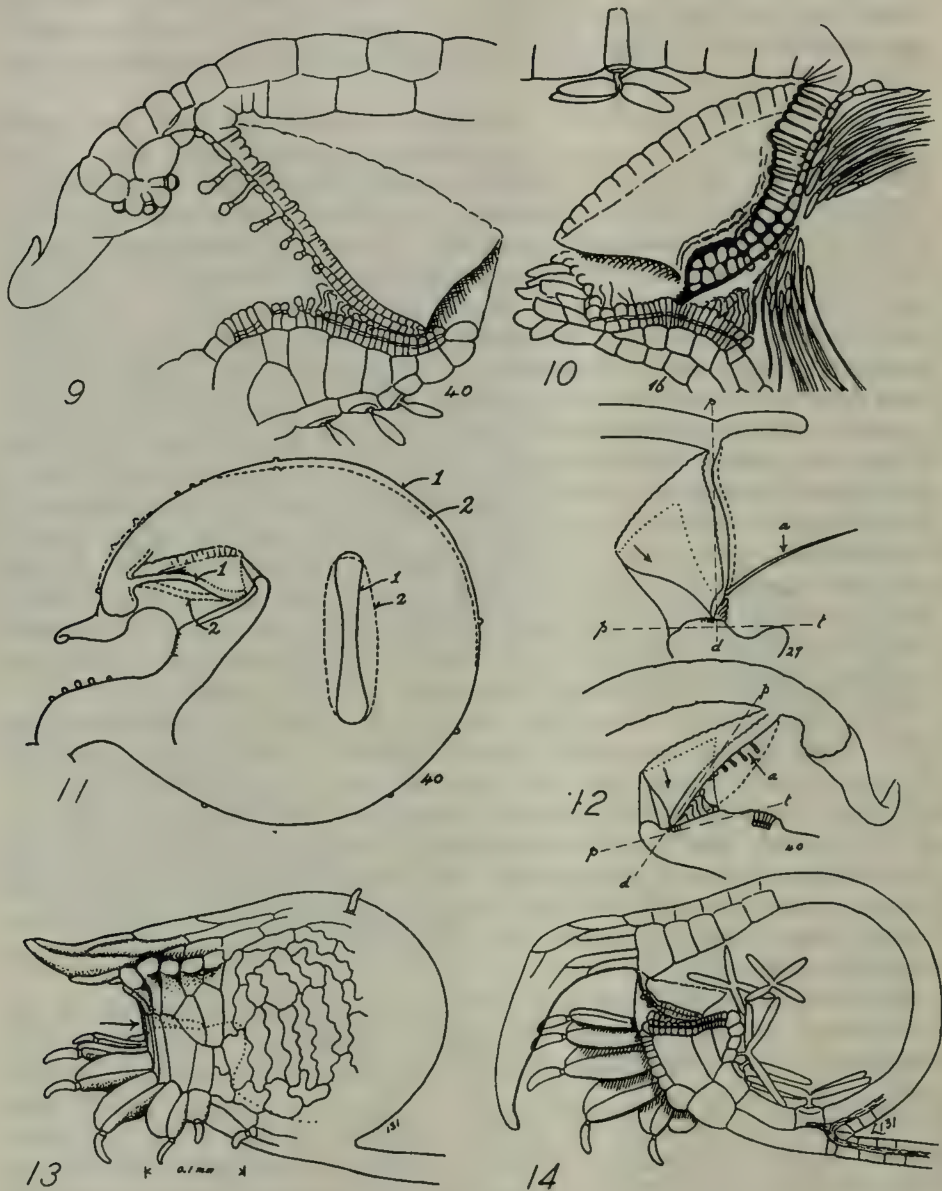
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PLATE II—References.

Fig. 9. Sagittal section of *U. cœrulea.*

Fig. 10. Sagittal section of *U. globulariæfolia.*

Fig. 11. Sagittal optical section of an entire trap of *U. cœrulea* showing the posture of the door and the profile of the entire trap when in the set condition (1), and after actuation (2). Inset: longitudinal view (diagrammatic) to show the form of the trap as thus seen before (1) and after actuation (2).

Fig. 12. The posture of the door with respect to the threshold in the *U. vulgaris* type (above), and in the *U. cornuta* type (below). *p.d.*, the plane of the door axis; *p.t.*, the plane of the threshold axis. (Compare Figs. 5 and 23 for a better idea of the proportions of the threshold, narrow in the *vulgaris* type, broad in the *cornuta* type.)

Figs. 13 and 14. An unnamed species from Ceylon, closely allied to *U. lateriflora.* Fig. 13, the entire trap; Fig. 14, the same in sagittal section.

trap is completely relaxed. Then the door becomes quite convex, the lower part of the door resting on the threshold for a long distance (Fig. 11). In the set condition, the posture is reversed. The door, as viewed laterally, becomes distinctly concave, and only a relatively narrow strip along the door edge rests on the middle zone of the threshold, the edge abutting on the raised-up inner zone. It will be seen that this exactly parallels the case of *U. cornuta*. The profile of the trap as a whole shows similar changes, from which it is seen (Fig. 11) that the overhang above the entrance shares in the flexures which bring the door into the position of efficiency in the set condition. These observations rest on a careful examination of living material, using the same technique as in the case of other species, photographing the living trap before and after actuation, and thus obtaining profiles of the door and neighbouring parts.

As compared with *U. vulgaris*, *U. cœrulea* is not so easily actuated, nor does it engulf air with the same readiness (Fig. 12). The entrance is narrow and the water film does not enter so readily, so that the trap may be exposed to air a long time before anything happens, if at all. While I have seen traps with air in them, I have not succeeded in seeing the spontaneous act.

The Type U. monanthos.

The species of this type, which has never been seen elsewhere (*volubilis*, *Menziesii*, *dichotoma*, *monanthos*, *violacea* and *Hookeri* are known to me), are all Australasian. I am indebted to my genial correspondents, Mrs. Eileen R. Johnson, Mr. Allan McIntyre and Mr. A. V. Giblin, for excellent material.

In form, the trap is peculiar and very distinctive, either almost circular in lateral view, or oval ; but the distinction arises in the combination of form with two pairs of wing-like appendages, one pair running from the stalk to the lower angles of the entrance, the other on the shoulders of the trap leading to the upper angles of the entrance. Overhanging the entrance is a proboscis, downwardly curved over the front of the entrance. Specific differences are to be found in the greater or less amount of laciniation of the wings, etc.

The approach to the entrance has, below it, a large patch of globose glandular trichomes, to act presumably as a lure. The entrance opening is circular, or nearly so, and is guarded by a thick, circular velum, somewhat less ample above, arising from sessile trichomes lining the inner surface of the wall of the approach to the threshold proper. This circular velum is altogether peculiar to this group of species. The upper part of the door is so placed that it rests in contact with the circular velum,[5] its patch of low glands being exposed at the opening. The threshold is very deep and bends downward toward its inner border ; there is here no upturned surface to resist the thrust of the door edge. Indeed, the inner end of the door bends down over the ridge of the threshold. From inner angle to inner angle of the threshold the door, therefore, has a sharp permanent downward bend, the effect of which is to increase resistance

[5] I have, of course, not seen living material. It would take adequate study to be certain of the exact door posture in the living trap.

to longitudinal flexure of the door upon actuation. The upper part of the door is wider than the lower part, forming a large convex surface, easily flexed by contact through the circular port formed by the velum. When this has been caused by the movement of some animal, the pressure of water continues the flexure till it reaches the transverse bend near the door edge. The sudden reversal of this bend results, in my opinion, in the snap action, which has been observed, following my suggestions, by Mrs. Johnson. She assures me that such snap action occurs, the changes in contour of the lateral walls and the engulfing of air having been observed by her, as also by Mr. McIntyre.

The door is peculiar in shape in having an extensive upper region, wider than in the lower region, and thin. Near its attachment to the wall of the trap, and where the maximum bending occurs when the door opens, the outer course of cells is thin. Elsewhere the two courses are approximately equal in thickness, except in the lateral reaches of the lower region, where these areas exert downward thrust on the middle piece. The transverse curvature of the door in this region is not as sharp as in such forms as *U. capensis*, but this is compensated for by the transverse flexure of the door in bending down over the back part of the threshold. In order to understand how important this flexure is we must appreciate that it is not a straight flexure, as a bend in a piece of flat paper, but a curved one, like the bend between the rim and crown of a bowler hat. The overcoming of the thrusts afforded by this arrangement is the peculiar feature of the action of this type of door. The effectiveness of the watertightness in view of the extensive outwardly bowed upper region of the door is procured by the extensive velum, supplemented by the adjunctive or secondary velum arising from the trichomes on all sides of the entrance in front of the threshold. The whole arrangement must be of a high degree of efficiency, and the in-pull of water great, as the sides of the trap are thicker than elsewhere, whereas in the other types the walls are of equal thickness on the flanks, with the exception of *Polypompholyx*, as we shall shortly see.

The actuation of this trap appears to be of the same manner as the previous forms described—namely, pressure on a thinner area of the door, occupied by a group of sessile glands on the surface and so placed as to fall nicely within the hole formed by the ring-shaped velum. This rather definitely points to the function of the sessile trichomes on the upper part of the door, no less for the previous groups of species described than for this—namely, as an area of contact by entering prey, possibly attracted thereto.

Polypompholyx.

In spite of the presence of most of the usual structural stigmata (for I failed to find the velum), in my previous publication (1932) I leaned toward the view that the door of this plant (of which two species, much alike, exist) acts as a simple valve, in the sense meant by Darwin for *Utricularia*. At my request Mrs. Johnson was kind enough to make careful observation of the living traps. Her notes, accompanied by sketches, leave no room for doubt that snap action occurs. I have made

another attempt to determine the presence or absence of a velum with material which had been preserved in weak formalin, in which the delicate membranes of the velum are not at all well preserved, as I have noticed repeatedly in other species, but I have found sufficient indications of the velum in the form of very mucilaginous and swollen, as it were semi-hydrolysed, remains of the membranes. It is not clear whether the velum arises solely from the threshold or also from the glandular trichomes just beyond the front of the threshold, and until I obtain well-preserved material (in alcohol) the point cannot be settled.

The threshold is approached, not from in front, but from the sides, as the projecting rostrum, the end of it resting on the enlarged stalk, obstructs direct approach. There is thus formed, as I have explained elsewhere, a sort of atrium, lined with great numbers of long, whip-like, glandular trichomes, the same sort occurring on the door itself, which forms the roof of the atrium. The capital cell of these trichomes is very long and slender, each secreting at its tip a droplet of mucilage. It may be that in the living condition these trichomes fill the atrium and act as a contributory velum. The actual entrance over the threshold is relatively very small and hedged about inside with up-jutting trichomes arising from the curved tissue shelf, in the front part of which is the pavement epithelium. This occupies a narrow strip on both sides of an angular ridge forming the front edge of the shelf. This ridge continues laterally to a point about half-way up the slope of the threshold, where the threshold pavement is very narrow. From this point it widens, fanwise, to the articulation of the door with the threshold, affording a wider out-sloping surface of application of the door thereto. The outer and inner zones are broader at the middle and narrower at the sides of the threshold.

The door, as seen *en face*, differs a good deal from the previous species examined, in that it is nearly circular in shape, save for the segment cut off by the door edge, making it rather more than semicircular. The upper region is very thick, the inner course of cells being very deep and richly supplied with props, and capable of much compression. The middle piece gradually thins and is curved, and just above it is a weak, thinner region, marked by the presence of a number of small, sessile glands. This region lies between the upper region of the door, which is covered with a dense mass of the aforesaid whip-shaped, glandular trichomes, and a narrow strip above the door edge, which engages the threshold. The manner of this recalls the condition which is described above for the *monanthos* type—that is, the lower edge of the door is applied to a ridge in the threshold, over which it is bent; but the dimensions of the parts are different and the condition is not so striking. The lateral reaches of the door are applied to the fan-shaped, outwardly sloping surfaces of the ends of the threshold.

The actuation of this trap must be regarded (in the absence of actual observation) as being in the same manner as that of *U. dichotoma*, etc. The middle piece is held tightly against the ridge in the middle reach of the threshold by the thick lateral portions of the door, which exert a strong downward thrust. As a matter of observation, the lateral portions of the door are thick, in this being commensurate with its thick

dimensions, as seen in the sagittal section. The very great thickness of the hinge region of the door gives the impression of the need of an adequate and unusually large amount of available energy for actuation, and in this connection we recall that the trap is triangular in form (regarded transversely), and that the walls of four courses of cells are very thick. The roofing wall, as well as the lateral walls, were observed by Mrs. Johnson to be concave in the set condition of the trap. It may be argued that, roughly speaking, there is available rather more than 33 per cent. more energy than in a trap with only side walls. The trap is certainly a much more stalwart structure than usual, and can be compared in this only with the type of trap represented by *U. globulariæfolia*.

The Type U. globulariæfolia (Fig. 10).

With this are several species having traps very much alike—namely, *U. amethystina*, *U. tridentata*, *U. modesta*, and *U. Roraimense*, and, according to Merl's (1915) notes, *U. bicolor*, all New World, neotropical probably.

The general form of this type of trap was described by Merl. It is a thick-walled and, in lateral view, well-rounded structure, with the stalk and entrance approximated. From the stalk leading up to the lower lip of the entrance there is a narrow but deep ramp, clothed along its ridge with long, backwardly curved, glandular trichomes in several rows. The overhang, which is massive, is forked, forming two strong antennæ, also clothed with the same kind of trichomes in rows. All these rows of trichomes converge at the door, against which the innermost trichomes lie, forming a thick circle and, it would seem, an accessory velum at the door surface (somewhat as in *U. monanthos*), and a long, funnel-formed guide to lead prey to the middle region of the door, which is there clothed with sessile trichomes.

The door is relatively small and nearly semicircular in outline, and is of nearly equal thickness from insertion to edge, though the inner course of cells is thicker toward the insertion. In some species, along the inner aspect of the free edge, runs a strip of beading in the form of three or four sharp ridges, which may serve to engage the edge of the door against the threshold. Its entire absence, however, in some species, throws doubt on such an interpretation. The angular divergence of the door and threshold is here much greater than in preceding forms, and the thrust of the former on the latter is very direct, the water pressure on the door having the effect of increasing the angular divergence and thus procuring a still more up-and-down thrust.

The threshold is rather narrow and is supported on a deeply reaching shelf of peculiar and graceful form. The outer and middle zones are flat, the inner having a velum. The middle zone is very compact. The inner zone slopes away, facing inwardly. Its capital cells become more rounded and more loosely packed and always bear remains of enlarged cuticles, these cells having been subject to the general inflation of the cuticular investment giving rise to the velum. Whether the peculiar form of the tissue shelf which bears the threshold plays any part in the adjust-

ments which take place during the setting of the trap after actuation is a question which may well be asked, but there is no sure answer ; yet it may be recalled that Brocher (1911) entertained some such idea in regard to *U. vulgaris*, but I think without objective justification. I think the bolster of tissue in such forms as *U. vulgaris* is capable of resisting changes of shape, but if this is the case it does not preclude the possibility from other forms.

The histology of the door deserves remark. The inner course cells of the middle piece, or rather the region of the middle piece and the area above it, where the sessile glands on the outer face of the door are situated, are of long cells, running longitudinally to the edge of the door, as far as the beading. These cells are, moreover, very richly provided with folds and props, indicating great flexibility in precisely that region, the middle piece, where in other forms there is a tendency in the other direction, namely, of rigidity. This condition is to be met with also in the cells of the central hinge in *U. vulgaris* and similar forms, a point where great flexibility in various directions is present (Lloyd, 1932). In the *globulariæfolia* type, the degree of complexity arising from folds or corrugations in all directions is very great indeed. The effectiveness of the application of the door edge on the threshold lies in part in the considerable curvature of the door edge, so that the line of contact is itself nearly the arc of a circle.

With this type we conclude our remarks concerning these foregoing types which may be collectively subsumed under one generalisation—namely, that they are all forms in which the actuation of the trap is procured by the inbending of a more flexible area of the door, thus upsetting the unstable equilibrium set up by the physiological activity of the walls in expelling water, a state of reduced water pressure within being preserved by the somehow engaged door rendered watertight by a velum.

In this type, however, we have departed from those in which there is a small angle to one in which that angle is quite wide, and the application of the door to the threshold is along its edge. In this, the trap is like that of *U. vulgaris*, but is otherwise quite of its own kind. Not in this type is the pose of the door surface against the threshold insured by the downthrust of its lateral regions. This thrust is now oblique with relation to the threshold, pushing the door edge forward to engage the front of the middle zone. The rigidity of the door in its efficient closed position is assured by the slope of the sides of the threshold, which faces outward ; thus the threshold is a short half-funnel into which the door (being longer along its edge than the threshold) is cramped, so that the greater the water pressure the tighter the contact of the lateral regions of the door against the resisting threshold.

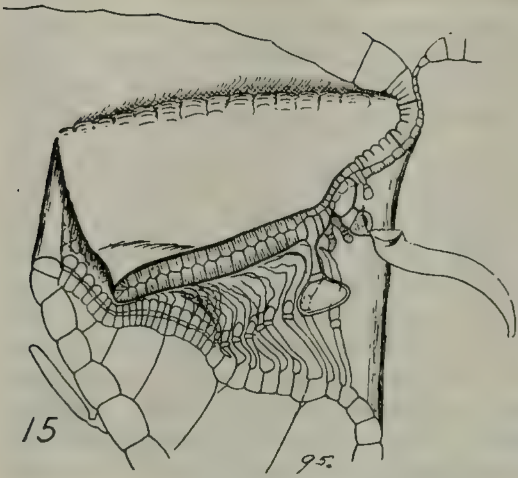
We pass on to consider another series of types, contrasting with the foregoing by having a special tripping mechanism, consisting of long bristles or glandular hairs protruding from some point of the door surface and correlated with the structure of the door itself. We shall consider first a curious Asiatic species which appears to stand in a position intermediate between those which we have already considered and those which are distinctly typical, e.g. *U. vulgaris*.

The Type U. orbiculata (Figs. 15, 16, 18).

If a bizarre structure warrants using this species as a type, the choice is justified. The plant was first described from the point of view of the morphologist by Goebel in 1891. I have been able to include Goebel's Ceylon collection in my studies and I have regarded this material as the typical *U. orbiculata* Wall. It is curious that no other collections sent to me from India and Ceylon have yielded species with the characteristic tubers of the Goebel material, which he described. All the other species sent me are very closely akin to the one before us and, at all events, the traps are alike. The trap is pear-shaped in lateral view, with the stalk affixed just in front of the middle point of the ventral side. Above the oblique entrance there is a short rostrum, giving rise to two thick downwardly and outwardly curved antennæ, bearing numerous uniseriate branches or cilia, each ending in a rather large, globose, glandular capital cell. The aspect of this apparatus distinguishes this species and its related ones indisputably. The trap is small, scarcely ever longer than 1 mm., exclusive of the antennæ.

When the sagittal section of the entrance is examined, it resembles closely that of *U. capensis*, but on study certain important differences appear. The threshold, as in *U. cœrulea*, is sharply uptilted near its inner border, and has an unusually deep sulcus running transversely ; in this the door edge rests along the edge of the middle piece, which is narrow. The door edges along the lateral reaches slope up on either side to the inner angles of the threshold. There is a velum supplied by the cells of the outer zone of the threshold, this being the primary velum, homologous with that found in other types. In front of the threshold the forecourt leading thereto is lined, as in *U. capensis*, with a clothing of stalked trichomes, graded in length, the shorter the nearer the threshold, in such fashion as to continue the general surface of the latter, thus forming a narrow channel leading from the outside to the threshold. These trichomes produce long, expanded cuticles which form a secondary velum, supplementing the primary (Fig. 15). The membranes are voluminous and entirely fill the space fronting the door as far as its middle point. We have seen that a secondary velum is thus produced in the *U. monanthus* type, except that in *U. orbiculata* there is no secondary velum above the entrance, but merely for the stretch of the three-quarters cylindrical forecourt. Only in *U. monanthos*, etc., the trichomes supplying the secondary velum are scarcely distinguishable from those of the threshold proper.

But it is the door which furnishes the bizarre feature. In general proportions it resembles that of *U. cœrulea* ; it is not long and narrow, nor is it semicircular, but something between these extremes (Fig. 18). As seen in the sagittal section, its posture is oblique with reference to the threshold, and correspondingly the lateral hinge regions are extensive and well developed, and exert a downward thrust which applies the middle piece tightly to the middle zone of the threshold. The middle piece is laterally not extensive and is composed of smaller cells than those of the hinge regions on either side ; nor is it sharply differentiated from



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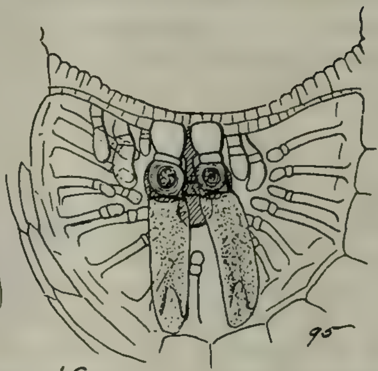

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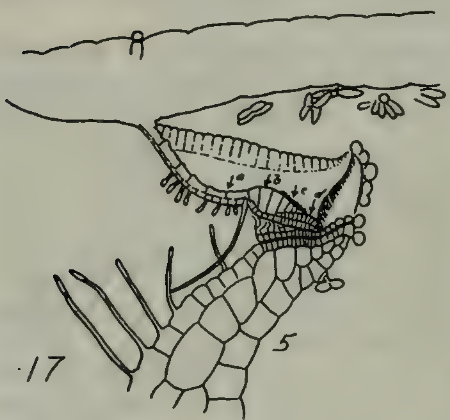

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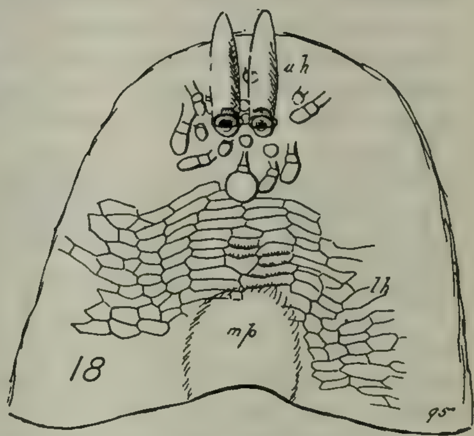

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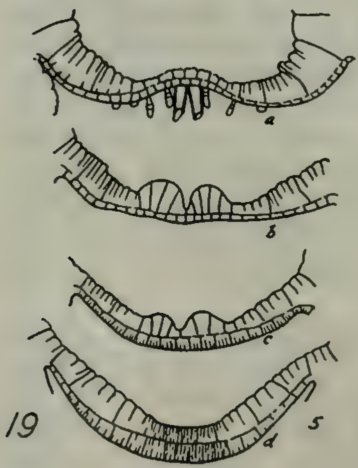

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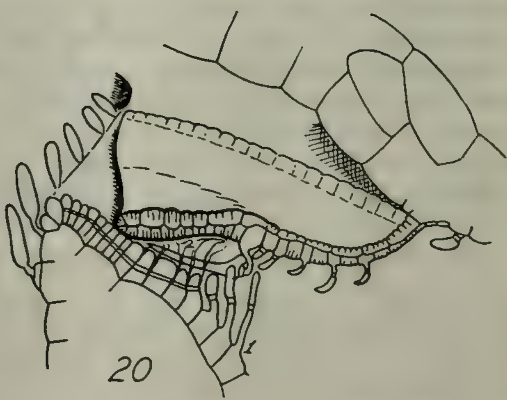

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PLATE III—References.

Fig. 15. *U. aff. orbiculata.* Sagittal section of the entrance structures.

Fig. 16. The same. View looking into the mouth of the trap.

Fig. 17. Sagittal section of *U. Kirkii.*

Fig. 18. *U. aff. orbiculata.* The door *en face. u.h.*, upper, and *l.h.*, lateral hinge; *m.p.*, middle piece.

Fig. 19. Transverse section through *a*, *b*, *c* and *d*, Fig. 17.

Fig. 20. Sagittal section of entrance of *U. capensis.*

the tissues above, as far as nearly the mid-point of the door. This whole stretch is rather massive, however, up as far as a middle region which forms a small oval or rounded area occupying a space just above the mid-point, and which is slightly convex, especially on the inner surface. This spot bears a group of, for the most part, short, clavate trichomes, but among them are three very peculiarly constructed trichomes. These are larger and stand out boldly, and are of two kinds. A single one is in the form of a large club with a slightly oblique head, the capital cell. This stands at the apex of an isosceles triangle, with the base above, and at the angles formed by the sides and base stand the two other trichomes which have the following structure. The basal cell is large and oblique and set deeply in the door, so that the inner course of cells beneath is very shallow. The basal cell is capped by a large mid-cell which in turn bears the capital cell, the cuticle of which in its definitive condition is shaped like the cowl of a ship's ventilator (hence called by me the cowl trichome). Within the cowl is a rounded, thick cellulose wall, from one side of which, beneath the upper limb of the cowl, extends a long, tapering mass of jelly-like material, which is so transparent that it is difficult to see. In order to photograph it I have stained it with ruthenium red. Its inner end is cupped, indicating, by its interior surface, where it was applied to the rounded cell wall remaining within the cowl. The jelly-like mass, except when torn or otherwise damaged, has always a tapering, horn-like form, curved much as a cow's horn, and it stands out in front of the entrance, pointing forward and downward.[6] If one faces the entrance, looking into it, one sees the two gelatinous horns pointing forward, and behind them the single club-shaped trichome, the whole blocking the space left by the radiating trichomes which supply the secondary velum (Fig. 16).

The region of the door above the trichomatous patch is usual hinge tissue, the outer course being thin, reversing the relation of the courses in the former, the structure of which indicates easy bending and can be regarded as a sort of central hinge, such as we shall find in *U. purpurea*, movement of which, on the contact of prey with the protruding three trichomes described, can be procured sufficiently to upset the unstable equilibrium of the system. Yet to what complexity has the apparatus in this type been developed as compared with that in *U. cornuta* or even *U. cœrulea*—and, it would seem, to no better end, no more efficiency gained. It may help to regard the gelatinous horns as a lure, but we cannot be sure that they are. Their soft and yielding nature does not recommend them as a releasing mechanism to assist in actuating the door ; only that we do not know even how yielding or otherwise they are relatively to the movements of small prey. That not only small but relatively large prey can be caught there is no doubt. I have seen a worm twice as long as the trap itself lying coiled up inside, which had evidently been caught at a gulp, since if they are caught by the pinching of the door they usually stay in the position caught.

[6] My earlier description of the gelatinous horns (1932) is faulty.

The Type U. vulgaris (Figs. 21–24).

Of the members of the genus, no species has been more under examination than *U. vulgaris*. F. Cohn and Darwin were the leading students of an earlier day (previous to 1882): it was then accepted that the door was a simple, inwardly moveable valve, which the prey opened easily by pushing against it. Its recurrence to its original position prevented escape. We need not recount at length the views that the bladders were floats, about which there was a lot of discussion finally closed by Goebel (1889). It was not till Brocher (1910) made the important observations that the bladders engulf air when a plant is raised from the water, and was led to see that only when the trap is set, that is, when it is in a condition of unstable equilibrium brought about by the exhaustion of the water content, that it can do so, he appreciated that the trap is watertight, but thought it merely plugged with mucilage, and that the trap could act but once. Merl (1921) found that the action of entrapping prey could be repeated, and determined the time necessary for the renewal of that condition of unstable equilibrium, namely, 15 to 30 minutes—observations which were made also by Czaja at nearly the same time. It was not quite certain to Merl that the whole action (aside from the exhaustion of the water from the interior of the trap) is purely mechanical, but Czaja took this position definitely. Recently M. Kruck (1931) has resuscitated the view, never very firmly held, that the action of the door is a sequel of the transmission therethrough of the stimulus from the protuberant, stiff, 'irritable' hairs: but this has nothing to support it. It is a curious fact that none of the above-mentioned observers, nor any others, had observed accurately the position of the door and its mode of contact with the threshold, nor had anyone save Withycombe suspected the inadequacy of Brocher's idea of the way in which the watertightness of the door is procured. For my part, I have shown that this is due to the presence of the velum, that the contact of the door and threshold is a delicate adjustment involving a tripping mechanism, and that the whole action is mechanical and depends for its efficiency on the physical properties and adjustments of the various parts. What these are may now be briefly summarised.

The door may be a continuation of the upper wall above the entrance (Fig. 24), or it may arise from a projecting overhang, e.g. *U. gibba* (Fig. 21). This produces no observable difference in the sensitivity of the mechanism. In any event, the door is very delicately constructed, in some species surprisingly thin, e.g. my No. 27 from Tropical Africa—a *U. gibba*-like form. The shape is nearly that of a quarter-spherical surface, one edge being attached to the walls of the trap, the other constituting the free edge of the door, the convex surface being turned outwardly. A wide outer zone is flexed in front (that is to say, in the middle third of the door), so that it is here concave and may be regarded as a hinge, or, at all events, a region where the maximum bending can occur, as when the door is opened. The outer course of cells is very thin; the inner, thick and richly provided with transverse corrugations supported on the ends of props (observed by Meierhofer, 1902) in the radial walls (Lloyd, 1932). These cells are elongated radially in the door and, in

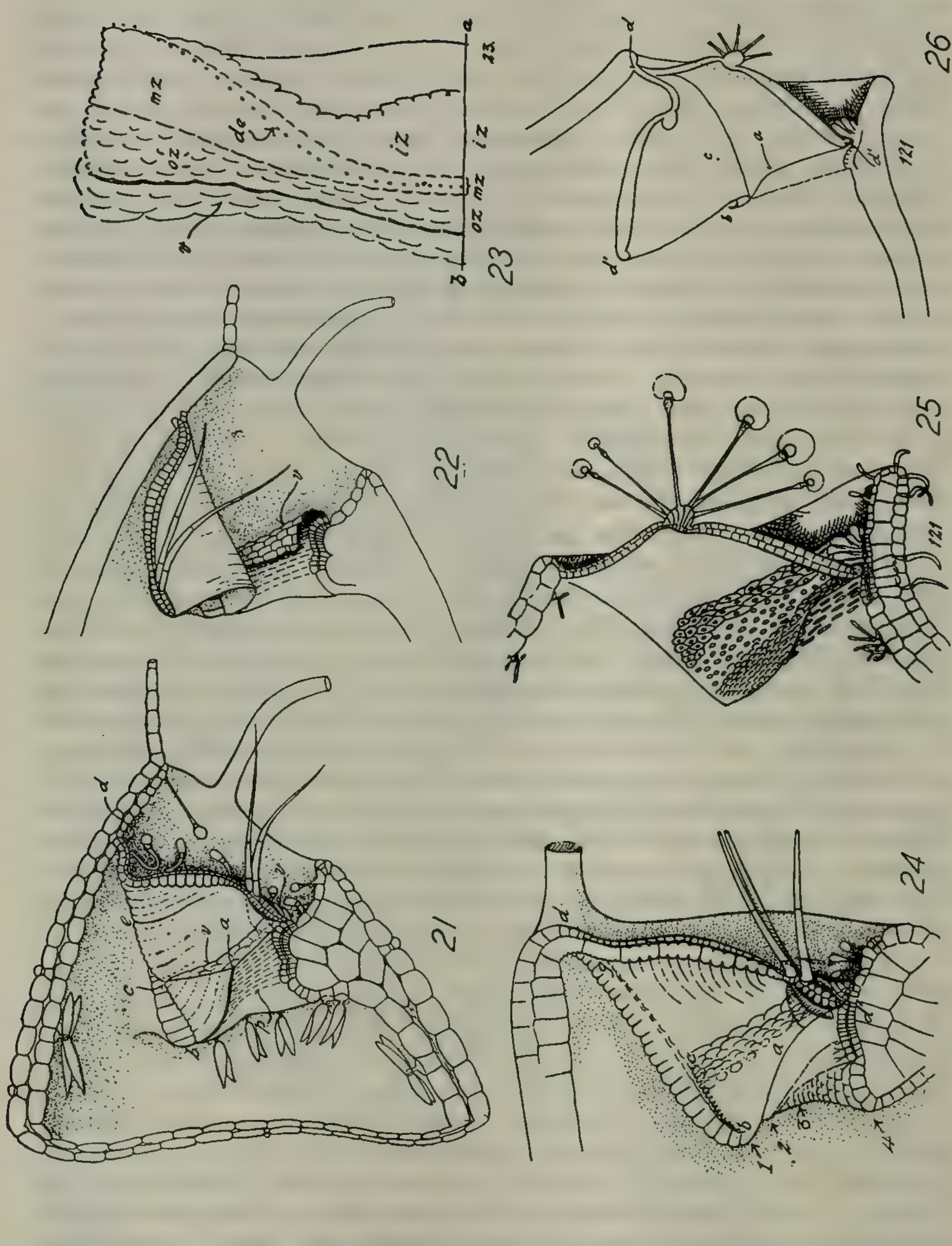
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PLATE IV—References

Fig. 21. Diagram of sagittal section of *U. gibba* entrance structures, in the set position ; and

Fig. 22. The same with the door approximately wide open.

Fig. 23. Diagram of one-half the threshold of the *U. vulgaris* type. *o.z.*, *m.z.* and *i.z.*, outer, middle and inner zones ; *d.e.*, door edge, position of the door edge as it rests on the threshold ; *v.*, velum.

Fig. 24. *U. intermedia.* Sagittal section, diagrammatic, with the releasing movement of the middle piece.

Fig. 25. Diagram of the sagittal section of the entrance of *U. purpurea.*

Fig. 26. Diagram of the same, indicating the posture of the door when in the set and open positions.

the middle area thereof, fade into a somewhat different form of cell, in which the corrugations are very prominent and regular and have given rise to some misrepresentation. The corrugations are continuous from cell to cell, and are very regularly concentric, giving the impression that they are the walls of isodiametric cells. The centre thus indicated lies just at a point where the door is at its thinnest, the central hinge, and immediately below this thin spot issue four (sometimes abnormally more) gracefully curved and pointed, stiff, three-celled trichomes. These are the tripping hairs, and constitute mechanically a latch lever. At their bases they are inserted close together in the upper part of a thickened mass of tissue, with courses of cells of equal thickness, the middle piece. This is slightly thinner along its middle line, that is, in the sagittal plane. When the door is opened the middle piece folds inwardly along this line. It acts as a mechanical unit with the latch lever, any movement of which disturbs the edge of the door one way or another, in any case effecting its release from a slightly outwardly turned surface of the threshold against which it rests. On either side the middle piece merges quickly into the outer hinge tissue.

The threshold, supported on a strong, upturned bolster of tissue, is nearly circular in axial view, its arc length being shorter by about 10 per cent. than the edge of the door (Lloyd, 1932). Since it is the door edge which lies in contact with the threshold, its curve lies obliquely from its point of attachment—the inner angle of the threshold—to a point in the middle in front of the middle zone. This is raised slightly, affording a resting-place for the door edge, resisting its inswing. At the sides the front surface of the door rests on triangular areas of the threshold at each end, these areas facing obliquely outwardly, so that the door under the pressure of the outer water is tightly cramped into place. The outer zone, wider at the sides than in the middle, carries a velum, consisting of several rows of bladdery cuticles, to which is attached a loose membrane arising from the cells of the middle zone and, to some extent, of the outer zone. The total threshold surface is shaped in correlation with the emplacement of the door edge. Important is the angle of divergence between the plane of the door and that of the threshold, which approaches 90 degrees, whereas in the series previously considered (*U. globulariæfolia* excepted) that angle is a narrow one (Fig. 12). That is, (*a*) the position of the surface of resistance for the emplacement of the door edge is in front of the threshold when the angle of divergence is great and in the back when that angle is small ; (*b*) in the latter case also the thrust of the sides of the door is directly down on to the threshold, while, when the angle of divergence is large, this thrust is directed obliquely forward, toward the middle point of the door edge ; (*c*) the outer zone is wide, furnishing a very wide and ample velum when the angle of divergence is small, or narrow when large.

Actuation of the door occurs when the latch lever is touched in any direction. Many trials have failed to convince me that the sensitivity of the mechanism is greater for one direction than another. This can be understood when one sees that an upward swing of the middle piece frees it from the resisting threshold ridge, while a downward swing releases

short lengths of the door edge on either side of the middle piece. In either event the result is the same. The inward movement of the door under the pressure of a column of water consists first in a longitudinal flexure of the middle piece, which, as the reversal of door curvatures advances, becomes curved inwardly. The flexures then move into the lateral hinge areas together with the outer hinge, reversing the curvature of the whole door. At the top of its swing the door edge is simply curved in the arc of a circle (approximately), and the opening, as seen by the observer stationed so that he may look into the trap along its axis, appears circular, or nearly so, the threshold forming the lower arc, the door edge the upper. I have satisfied myself that this is a correct record of the movement, by taking motion pictures at high speed (160 frames per second), which I shall have the pleasure of showing you. This seems to be a simple enough matter, but, as it has been described otherwise, it is not superfluous to have spent some effort in getting at the facts.

It is an interesting cell structure which allows such free movement, which is at the same time completely reversible, so that the door springs at once into its original position on the slacking of the water column. The whole movement occupies $\frac{1}{35}$ second. Furthermore, one may play with the door with a not too sharp needle point or with a minute glassbead, moving the door hither and yon, with no harmful effect. There is an admirable elasticity and flexibility of the tissues which fit its needs (Lloyd, 1932).

U. resupinata.—In describing the above I have erred to a purpose in regarding all the species of the type *U. vulgaris* as submersed, freely floating forms. There are some exceptions, all (?) American species. *U. resupinata* will serve to illustrate a small group of species which are terrestrial to the extent that they grow anchored in the bottom of ponds where the water is shallow, or in similar situations (wet sand, etc.). In *U. resupinata* the traps are dimorphic, larger ones growing on the terete green leaves, and supplied with the *vulgaris* type of appendages (branched antennæ and lateral bristles), and small ones on the underground parts, with appendages much reduced or absent. The middle piece of the door is somewhat more massive than in *vulgaris*, but, aside from this, there is no notable difference.

Another exceedingly curious plant is *U. neottioides*, belonging to Kamienski's segregate *Avesicaria*—a poor name for a plant with abundant traps. The plant grows in running water, attached to more or less solid substrata. The stolons in contact with hard surfaces grow and appear after the fashion of *Podostemon*. From these arise free stolons with linear, leaf-like branches, and near the axils occur the traps, which are peculiar in having the entrance and stalk at opposite ends. One may imagine this to be correlated with the movement of water, the trap being stream-lined and the entrance where the back-swirl occurs. The structure of the door and threshold is practically identical with that of *U. gibba*. The antennæ are very small and bear one or two short branches.[7] The

[7] It would be gratifying to see good material of *U. rigida*, another species growing in 'swift-running water' and attached to the substrata. It is said to be devoid of traps (Stapf, *Flora of Tropical Africa*). Later: the material has been seen at Kew, but no traps were found.

actuation of the trap is accordingly by pressure on the bristles, not seen by von Luetzelburg, who gave a good description of the plant as a whole.

U. RENIFORMIS.

This plant, well known in cultivation in our greenhouses, is a large, orchid-like species from the American tropics. Its habitat is in the wet moss and other compact epiphytic growth on stems of big grasses, trees, etc. The stolons are thick and white, and bear, for an *Utricularia*, very large reniform leaves, long flowering scapes with large, purplish flowers, and a lot of very minute traps, smaller than the traps of minute species, e.g. *U. gibba.* With this as typical are associated an array of species, severa of which are similarly large or, at any rate, of impressive size, such as *U. longifolia*, *U. montana*, *U. Lundii*, *U. Endresii*, *U. Glückii*, with some much smaller, even diminutive, species, of which I have examined *U. Dusenii*, also seen in cultivation. They are all neotropical, none of the type occurring in the Old World.

Except as to minutiæ of structure, there is really very little to say in comparison with the *vulgaris* type. Instead of the elaborately branching antennæ of the floating forms, in the terrestrial forms we are considering the antennæ are merely tapering horns, curved backwards or forwards, from an overhang curved downwards over the entrance. In this respect they ally themselves with *gibba* rather than with *vulgaris.* The stalk of the trap, which in lateral view is well rounded, is usually closely approximated to the entrance. The door is like that of *U. vulgaris*, but has a more massive middle piece, more so in some species than in others. Whether this difference indicates anything as to the delicacy of action or not it is difficult to say. The traps of *U. reniformis* do not seem to engulf air by any means as readily as those of the floating forms, and this may advantage them, growing as they do merely in a very wet environment and not submersed. In all cases actuation of the trap is achieved by contact with four latch-lever bristles. I have already pointed out that in form the trap of *U. cœrulea* looks like that of the *reniformis* type, the difference being revealed in the absence of the door bristles and in the possession of bifid trichomes instead, as in the American species, of quadrifids.

The threshold is so placed that the face of it is directed obliquely outwardly, giving a very characteristic form to the bolster of tissue which bears it. This position suggests that the trap is less easily actuated.

Three peculiar American and one African species can naturally be mentioned in this connection, all sufficiently peculiar to deserve specific examination. These are *U. Lloydii*, *U. nana*, *U. longiciliata*, and *U. Kirkii.*

U. Lloydii Merl in *MS.* is a small plant of terrestrial habit, bearing traps which resemble the *globulariæfolia* type in the possession of a steep ramp leading up to the entrance from the level of the stalk. The traps are dimorphic, the two forms being, in certain details of structure, very strikingly different. This dimorphism was first noticed by Merl, who drew my attention to it before I had examined the plant at all. There can be no doubt of the dimorphism, which, in lack of conclusive

evidence, would certainly obtrude itself. The two kinds of traps may be found on the same stolon, close together.

In the one form the door resembles that of the *reniformis* type, save that the middle piece is not so highly specialised. There is, however, but a single tripping bristle, straight, tapering and pointed. The basal cell and the next cell to it form a special stiff, hinge-like base. There are a few short, clavate trichomes on the upper part of the door surface. Over the general surface, both on the ramp and elsewhere, are scattered globular, sessile trichomes. In the other form there is no tripping bristle at all. The door carries numerous long clavate trichomes, and similar still longer ones are found along the ridge of the ramp and under the antennæ, which here resemble those of the *globulariæfolia* type. Thus one form of trap resembles *reniformis* and the other *globulariæfolia*. Neither Merl nor I have been able to correlate surely the distribution of the two kinds of traps with position on the plant.

The second species of the American triad, *U. nana*, also resembles *reniformis*, but is lacking antennæ, and for this reason recalls *cornuta*. We need not particularise further than merely to point out that, instead of there being only one tripping bristle, as in one form of trap in *U. Lloydii*, or four, as in *reniformis*, there are just two, standing side by side. Their basal cells are somewhat enlarged, but show no striking form such as noted in *U. Lloydii*. The structure of the door is, however, precisely like that in *U. Lloydii*.

The third species, *U. longiciliata*, was examined by Merl, who observed (1915) that there arises from the middle of the door, just above a massive middle piece, a single glandular trichome, consisting of a slender, cylindrical basal cell, a short mid-cell, and an ovate capital cell. In view of the massive character of the middle piece and the smallness of the trichome, it is not easy to believe that the door is actuated by contact with the trichome. The form of this trichome allies the trap with that of our last type, *U. purpurea*. The likeness is perhaps rendered still more striking by the fact that there is below the entrance a strong protuberance bearing two widely spreading branches. A single protuberance is to be seen in some of the allies of *U. purpurea*, though none in others. There is, moreover, also a small rostrum above the entrance, somewhat as in an Old World species described above (my No. 131, unnamed). Though the general type of trap, aside from the curious appendages, allies *U. longiciliata* with the *vulgaris* type, I am inclined to look upon it as indicating an alliance with *U. purpurea* on account of the door trichome.

Finally, here we must place a most intriguing type which I collected in Africa at the Victoria Falls, namely, *U. Kirkii* (Figs. 17, 19), identified for me by Dr. Rendle; and in this connection I recall the kindness of Dr. Saunders, who supplied me with vials for my collection, having been the more provident. *U. Kirkii* is a small, blue-flowered plant of terrestrial habit, growing in ground where there was abundant seepage, with a trap looking to be almost identical with that of *U. capensis*, but that the rows of the more slender peristomal trichomes below the entrance are raised somewhat on a collar, as in *U. albina*. Like *capensis*, too, it has a broad threshold, the lateral thrust of the door being downwards.

The upper moiety of the door, as seen in sagittal section, is uniform in thickness, with the outer course of cells thin, but somewhat thinner toward its lower limit, where it meets the middle piece. The character of its tissues marks the upper region as hinge. This hinge extends around the sides, forming much thicker lateral hinges. It is evidently convex (at least in the relaxed position), and is clothed rather densely with short, clavate trichomes. Just at the lower limit and close to the middle point (here the door is thin) there are two stiff bristles arising out of the outer course of cells. These extend downward and forward. The middle piece is quite thin along its sagittal line, just below the upper part of the door, but on each side there is a large bulbous protuberance. The two masses become thinner toward the door edge, to which they extend, and appear to be stiffening agents, giving rigidity to the middle piece in one direction without limiting its flexibility in the other. They are derived entirely from the inner course of cells (Fig. 19, *b*), merely by enlargement without additional cell-divisions, in the fashion in which the knob of the door of *U. purpurea* is formed (here from the outer cell course) (Fig. 25). It is evident that the thin line of door tissue between the bulbous masses is a longitudinal hinge.

The threshold is like that of *U. orbiculata*, with a deep transverse depression which receives the middle piece edge. The precise posture of the door when the trap is in the set position still eludes us, as the material could not be studied at the time of collection. It may be suspected that the posture represented in the diagram, while probably correct for the relaxed posture, should, for the set condition, be less convex, giving the middle piece a larger angle of contact with the threshold. We may be sure that this occurs, but precisely to what extent we do not know. In the relaxed position the tripping bristles appear to lie in the trichomatous clothing of the approach to the threshold. Less convexity of the door would result in bringing them up into a position which would seem to be a better one for their functioning. But in any event it seems fairly certain that their position is such that the prey should press down on them in approaching the door, their downward swing resulting in prying up the upper part of the longitudinal hinge.

As in the case of *U. orbiculata*, *U. Kirkii* combines some of the mechanical features of the *cornuta* type with those of *vulgaris*.

In view of the anatomical facts displayed, it would seem that actuation of the trap takes place as follows: Pressure on the two juxtaposed trichomes, inserted just above the two protuberances and so placed that impact will usually be from above, will push the upper part of the middle piece inwards along the middle thin line between the protuberances. This initial flexure allows the water pressure to act in the usual manner. The flexure travels upward along the middle of the upper region, where the door is relatively thin, and backward to the door edge.

The Type U. purpurea (Figs. 25, 26).

We have come to the last type to be considered, wholly American and chiefly confined to the tropics, or at least to South America. North America has the one species of which I have been able to study living

material, found growing in the vicinity of Montreal. It is well adapted to motion picture photography, and I show you some results.

Irrespective of species, the plant body consists of a main axis with verticillate lateral axes, each member of which normally bears a terminal trap. In some species the trap is wholly devoid of appendages ; in others a proboscis-like upturning extension of the lower lip of the entrance is to be found, e.g. *U. elephas* Luetz. The walls are thin and bear three kinds of trichomes on the outer surface (Lloyd, 1933), one of which secretes a fatty oil. The interior surface bears numerous quadrifids and a dense row of bifids on the inner flank of the threshold bolster.

From our present point of view the point of interest is the form and functioning of the door and threshold. These are, in structural detail, very different from the foregoing. The most readily observable difference is the presence of a radiating group of tripping trichomes, arising from a knob-like protuberance placed a trifle above the middle point of the door at the upper limit of the middle piece, which is here very large but fundamentally like that of *vulgaris*. The trichomes are of two kinds in *U. purpurea*, of only one kind in *U. elephas*, *U. cucullata*, etc. Each trichome consists of a long, tapering, terminally expanded cell bearing a short, disc-shaped mid-cell, this bearing a spherical capital cell with a much enlarged cuticle ; or, in other species, the end cell may be fusiform (Goebel, 1891). At the periphery of the tubercle the end cell is much smaller, as is the expanded outer end of the stalk cell. This difference has probably no significance. These are the only trichomes on the door in *U. purpurea* ; in *cucullata* there is in addition a patch of short, clavate trichomes forming an oval group below the tubercle.

The door consists of two chief regions, the middle piece below the tubercle and the sigmoid (the outer) hinge. The relative thickness of the two courses of cells changes as we proceed from the outer edge to the tubercle, so that the maximum flexure can occur where the outer cells are the thinnest, namely, just above the cuticle. It is here that the door chiefly bends on being opened. The lateral region is similar in structure to the outer hinge. The middle piece is massive, the cells being of equal thickness. The edge of the door is beaded with a three-quarters bead of some thickness, the bead being turned outward. When the trap is set this bead rests along the middle zone of the threshold, the velum resting against the door edge, over the beading.

The threshold is narrow in the middle, widening fanwise toward the sides, where the door is attached to it. In its narrower middle part the outer zone bears an ample velum, consisting chiefly of the ballooned cuticles of the component cells, the middle zone cells contributing little, contrary to the case of *vulgaris*. The middle zone is narrow, of small and compact cells, and is slightly dished to receive the door edge. The outer zone is unique in having the cuticles enlarged and filled with a stiff mucilage (a hydrolysed cellulose probably), forming a resisting ridge against which the door rests when the trap is set. The emplacement of the door otherwise is as in *vulgaris*, the lateral reaches lying against the broader lateral reaches of the threshold, where a broader zone of velum cells occurs.

Actuation of the trap can be caused by touching the glandular door-trichomes, when the trap is exhausted of water; in these species, owing to the thinness of the walls, it proceeds till the two walls are in close contact with each other. This is well shown if a trap which has swallowed a bubble of air is allowed to reset itself—a process which occupies about two hours in this species, four to eight times as long as in *vulgaris*. During this period the bubble changes shape in adapting itself to the changing contours of the interior, and this is well shown in the motion pictures. In whatever direction the trichomes are touched—the traps are not all equally (mechanically) sensitive—the actuation takes place. The explanation lies in the rotatory movement of the tubercle, and it is so poised that in whichever way it is moved, up or down, the effect is to raise the door edge a very slight amount, but sufficiently to upset the equilibrium.

Summary.

The foregoing account is based on the study of about 75 species of *Utricularia* (including *Biovularia* and *Polypompholyx*).

The bladders (called here the traps) appear in a great variety of form. The types selected to represent these forms illustrate the whole range of variety, so far as known.

The study of living material of a number of species shows that certain properties of the trap heretofore known to us from the study of chiefly *U. vulgaris* are possessed by all. These are, briefly, a watertight door, snap action on actuation accompanied by the inrush of a column of water carrying with it the prey responsible for the actuation, the immediate return of the door to its original position, and the subsequent exhaustion of water from the lumen of the trap resulting in resetting it. This resetting consists in the close adjustment of the door at all points with the threshold. The resulting posture of the door enables it to resist the even, if considerable, pressure of outside water on it, the watertightness being achieved by the sealing along the door edge by the velum. The effectiveness of the door posture depends on the shape of the threshold, which is always slightly funnel-shaped, the sides converging inwardly. In addition, there is a more markedly outfacing ridge or surface against which the middle reach of the door edge finds application, resisting the inswing of the door.

The structure of the door is correlated with the function of its various regions. It is composed of two courses of cells, the relative depths of which vary according to the function. While the whole is remarkable in its capacity for bending, we can recognise areas which can bend very freely and through a large arc. This is hinge tissue, in which one course of cells is thin, the other thick. The thick course always takes the maximum compression. The upper part of the door and the regions around the sides are hinge tissue. The capacity of compression and extension of the deep cells depends on their bellows structure, their periclinal walls being corrugated, each corrugation being supported by stiffening rods in the anticlinal walls. The occurrence of props in the anticlinal walls is general throughout the door tissues, so that the chief characteristic of hinge tissue

is the corrugation of the periclinal walls (inner and outer). The middle portion of the lower half (more or less) of the door has cell courses of equal thickness very strongly supported by large, numerous rods. The cells themselves become exceedingly small, especially as they approach the door edge. The structure is such as to give some and equal pliability in either direction, combined with considerable rigidity. This is the part of the door which has to remain in a rigid condition to give the door its footing on the threshold. The extent of these parts of the door varies with the species and peculiarities of shape of the entrance structures.

There are two general classes of trap :

(*a*) Those in which the threshold is broad (from back to front), the outer zone bearing a broad velum, the middle zone being broad also, and the inner zone narrow. The door in such cases is longer than broad, and is so placed that when the trap is set the door edge is held in position by the downthrust of the lateral hinge, contributing with longitudinal thrust to the firm application of the door edge to a more or less upturned surface near the inner limit of the threshold. The angle made by the plane of the door with that of the threshold is a small one. The door is devoid of special organs for actuation, unless sessile or short trichomes scattered on the upper convex surface of the door may be so regarded. At all events, actuation follows only on the application of sufficient pressure by prey trying to enter to make an initial dent in the surface. This allows the outside water to exert its pressure in folding the door lengthwise. The fold, travelling to the door edge, releases it from the downward thrust of the sides, and the door is opened. The action is by no means as vigorous as in the other kind presently described, nor as easily procured. But procured it can be, and is vigorous enough to carry in the intruding prey.

(*b*) Those in which the threshold is narrow. The outer zone is relatively broad, and bears an ample velum ; the middle zone is narrow in the middle, widening toward the sides relatively more than in the class (*a*), and with an inner zone which is broader. The surface of application of the door edge is at the front of the middle zone along the middle reach ; along the lateral reaches the surface of the door is applied to broader, fan-shaped extensions of the middle zone facing outwards, procuring the funnel-like shape of the entrance, into which the door is cramped under pressure of water. Here the velum also is broader and deeper. The door stands at a large angle to the plane of the threshold. It is provided with trichomes which constitute a latch lever for the actuation of the trap. Contact therewith disturbs the door edge sufficiently to allow the pressure of water against it to become effective in opening the trap and engulfing the prey.

One cannot boast that all the species fit nicely into one or the other of the above two categories. Beyond the general statement as made, each kind of trap demands its own description. One is impressed by the epigrammatic saying of the Italian botanist, Caruel, which was brought to my attention by Goebel in conversation about this very question, to wit : ‘ La pianta cresce crascuna alla sua idiosyncrasia.’

Bibliography.

BROCHER, F.: 'Le problème de l'utriculaire,' *Ann. biol. lacustre*, **5**, 33–46 (1911).
COHN, F.: 'Ueber die Function der Blasen von *Aldrovanda* und *Utricularia*,' *Beitr. Biol. Pflanzen*, **1** (3), 71–92 (1875).
CROUAN FRÈRES: 'Observations sur un mode particulier de propagation des *Utricularia*,' *Bull. soc. botan. France*, **5**, 27–29 (1858).
CZAJA, A. T.: 'Die Fangvorrichtung der *Utriculariablase*,' *Z. Botan.*, **14**, 705–729 (1922).
—— 'Ein allseitig geschlossenes, selektivpermeables System,' *Ber. deut. botan. Ges.*, **40**, 381–385 (1922).
—— 'Physikalisch-chemische Eigenschaften der Membran der *Utriculariablase*,' *Arch. ges. Physiol.* (Pfluger's), **206**, 554–613 (1924).
DARWIN, C.: *Insectivorous Plants*, New York, 1875.
GOEBEL, K.: *Pflanzenbiologische Schilderungen* (Marburg), Part I, 1889; Part II, 1891.
—— 'Morphologische und Biologische Studien. V. Utricularia.' *Ann. Jard. Bot. Buit.*, **9**, 41–119 (1891).
KRUCK, M.: 'Physiologische und cytologische Studien über die *Utriculariablasen*,' *Botan. Archiv.*, **33**, 257–309 (1931).
LLOYD, F. E.: 'The mechanism of the water-tight door of the *Utricularia* trap,' *Plant Physiol.*, **4**, 87–102 (1929).
—— 'The range of structural and functional variation in the traps of *Utricularia*,' *Flora*, **125**, 260–276 (1931).
—— 'The range of structural and functional variety in the traps of *Utricularia* and *Polypompholyx*,' *Flora*, **126**, 303–328 (1932).
—— 'Is the door of *Utricularia* an irritable mechanism?' *Canadian Journ. Res.*, **7**, 386–425 (1932).
—— 'The structure and behaviour of *Utricularia purpurea*,' *Canadian Journ. Res.*, **8**, 234–252 (1933).
—— 'The Carnivorous Plants. A Review with Contributions,' *Trans. Roy. Soc. Canada*, Third Series, **27**, App. A, 1–67, 16 pl. (1933).
LUETZELBURG, P. VON: 'Beiträge zur Kenntnis der *Utricularia*,' *Flora*, **100**, 145–212 (1910).
MEIERHOFER, H.: 'Beiträge zur Anatomie und Entwickelungsgeschichte der *Utriculariablasen*,' *Flora*, **90**, 84–113 (1902).
MERL, E. M.: 'Biologische Studien über die *Utriculariablase*,' *Flora*, **115**, 59–74 (1921).
—— 'Beiträge zur Kenntnis der *Utricularien* und *Genliseen*,' *Flora*, **108**, 127–200 (1915).
SCHIMPER, A. F. W.: 'Notizen über insectenfressenden Pflanzen,' *Bot. Zeitschr.*, **40**, 225–234, 241–247 (1882).
SKUTCH, A. F.: 'The capture of prey by the bladderwort. A review of the physiology of the bladder,' *New Phytologist*, **27**, 261–297 (1928).
WITHYCOMBE, C. L.: 'On the function of the bladders in *Utricularia vulgaris*,' *Journ. Linn. Soc. Bot.*, **46**, 401–413 (1924).

SECTION L.—EDUCATIONAL SCIENCE.

THE DEVELOPMENT OF THE NATIONAL SYSTEM OF EDUCATION

ADDRESS BY

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PRESIDENT OF THE SECTION.

I purpose this morning to follow the sound example of those of my predecessors who have confined their addresses for the most part to matters of which they have had first hand experience. My own experience during the last thirty years has been that of an administrator in a humble way, and I have therefore chosen as my subject 'The Development of the National System of Education.' I hasten to assure you, however, that I do not design to discuss more than one or two phases of that development. The title is comprehensive enough to enable me to bring under it all the things I wish to say, but an inclusive treatment of it would require more time than is at your disposal to-day, and a more competent exponent than I can claim to be.

It is vividly present to the mind of every educationist that he is serving a society which is disturbed by great private and public anxieties. The causes are world-wide. We see the foundations of social order and well-being shaking in country after country and we wonder how long our own land will be spared. In such times of unsettlement that man is happiest who, with a small thing to do, sees it and does it, who takes short views and lives a day at a time, like the caretaker of whom one read recently dusting the benches in the Parliament House while revolution was being made in the streets without. But the minds of thinking men are quickened by the turmoil and must work, and if at times they are depressed by a sense of helplessness, that is not the dominant note. It must needs be that changes come. By taking thought with their fellows, men can, it may be, help to determine the direction and extent of the changes. There probably never was a time when every department of social and economic life was more vigorously canvassed than it is to-day. Large conventions, which in normal circumstances men accept as the price of being allowed to get on with their work, are the subject of ceaseless debate ; the quiet corners which usually escape notice are ruthlessly being turned out, and proposals for reform come from every quarter.

Education does not sue to be excused from the general re-valuation. True that in one aspect it is a great institution with a membership of thousands of men and women, concerned like all institutions with the effects reform may have on the lives and fortunes of its members. True

also that the need for re-construction has notoriously been made a pretext for paying off private grudges against individuals and whole classes in society. Teachers—some teachers—are apprehensive of similar treatment, and are naturally stirred to take preventive action. Yet an educational system does not consist alone of schools, however numerous and well articulated one with the other, nor of teachers, however highly qualified : it requires to be informed by an understanding on the part of the community at large of the purpose of the schools and the aims of the teachers. In the first Presidential Address of this Section, more than thirty years ago now, Sir John Gorst defined the task of the British Association as the 'inculcation of a scientific view of things in every department of life.'

Education is such a department of life and it cannot function adequately and healthily unless the nation applies to it that trained organised common sense in which, as Huxley said, science consists. On this view it is the increasing manifestation of public concern for education which enables us to have an educational system at all, and if there are gaps, it is because our public have not yet learned steadily to regard the whole, but concentrate now on one part of the field and now on another like an infantry company advancing by irregular rushes. Out of the inquisition then to which education is being subjected, in common with other social services, will assuredly come a summons to advance which mere indifference can never give.

But the educationist and the teacher should not adopt a passive attitude toward the great debate, leaving it to go forward while he immerses himself in professional duties. He owes it to the service for which he is enrolled to think out his own position, to look before and after, so that where he hears education attacked or misrepresented he may be ready to explain and defend it. He will not be long in any company without having the opportunity. Teachers are often criticised, whether justly or not let them judge for themselves, for living wholly in an immature world of their own as a caste apart, different from other men. Exaggerated devotion of that kind in any sphere leads to unpopularity and loss of influence. There is a time to put off the gown : men are flesh and blood and apprehensive, and the teacher does right to meet them in the ways of the world as a man and not as a schoolmaster. I recall some words of Dr. Arnold's, written at the time when he was actively engaged with the establishment of the new London University and was writing his History of Rome. 'I hold,' he wrote, 'with Algernon Sidney, that there are but two things of vital importance—those which he calls Religion and Politics, but which I would rather call our duties and affections towards God and our duties and feelings towards men : science and literature are but a poor make up for the want of these.'

Nor are his pupils likely to suffer by this suggested diffusion of the teacher's interest. I have seen it said that Thomas Arnold found that his work with the Sixth at Rugby never went better than during that strenuous time. Routine, like a strangling weed, is only too ready to creep over any school with deadening effect, unless conscious efforts are made to keep it under. But where the teacher himself is a link between

the school and the world outside there is a freshness and rich actuality about his teaching compared with which mere formal or traditional routine is a feeble thing.

The development of an educational system in a democratic country such as ours is a difficult and complicated enterprise. Consider by way of contrast what is happening in certain other and ultra-modern states. You are struck at once by the dominance of a single leading idea, to which there is little that corresponds in our own society. In soviet Russia it is being said that the one purpose of education is to create active workers for the construction of a socialistic state. Of Germany much the same can be said. The Nazi Minister of the Interior only the other day declared that the time had come for abandoning liberal notions of free individual development. The child must be reared for complete absorption in and subservience to the corporative state. Whatever else we may think of it, this concentration on a single aim undoubtedly simplifies and speeds up the work of educational construction or re-construction. But for us such an immense simplification is out of the question. Our system of education has to meet, and if it may to adjust, many differing demands : the demand of the parent, of the community, of industry, of the state, demands which are not quite the same to-day as they were yesterday, and will not be constant to-morrow. And all these demands have to be reconciled with the demand that the child or young person shall be assisted freely to develop his individual character and ability. In the familiar words, ' adequate provision must be made in order to secure that children and young persons shall not be debarred from receiving the benefits of any form of education by which they are capable of profiting.' It is in this assertion of the rights of the individual that the English system of education differs fundamentally from those of our neighbours who are obsessed, as we think, with the notion of the omnipotent state. And it is because of this principle that the educationist disappoints many would-be reformers in our own country who wish to re-construct our education in the interest of early occupational competence.

Not that the educationist and those who hold with him are blind to social and economic necessities, but their concern is for the future Education cannot dispose of present emergencies any more than a tree can grow ripe fruit overnight. It takes a generation for its policies to come into full bearing. The men and women of to-day must deal with their own difficulties. The one thing of which we can be certain in these rapidly-changing times is that to-morrow will be different. It is, therefore, no mere theory but the soundest possible practice that we should develop the powers of youth that they may face emergencies, the nature of which we cannot predict, with moral courage, adaptability, and resourcefulness. But

> If we draw a circle premature,
> Heedless of far gain,
> Greedy for quick returns of profit, sure,
> Bad is our bargain.

The birth of this Section at Glasgow in 1901 came just between the passing of the two Acts which laid the foundation of our present educational system. The Board of Education Act of 1899, as its title implied, set up a State Department under a Minister for the superintendence of matters relating to education in England and Wales. It brought together two previously existing departments, namely, the Education Department in Whitehall, which since 1870 had been developing and systematising elementary education, and the Science and Art Department in South Kensington, which independently administered the Government grants for schools of art and science and generally promoted what we now call technical education. The Act passed with little public notice, for very few people outside the service saw it for the prelude that it was.

It was far otherwise with the Education Act of 1902, the second great statutory landmark in the development of our educational system—Forster's Act of 1870 being the first and Mr. Fisher's Act of 1918 the third and latest. The feature of this Act which attracted most attention, giving rise to bitter public controversy at the time, was that which enabled the voluntary schools, previously only state-aided, to receive assistance from local rates. The Church schools were put upon the rates, in return for some concessions to public control. Although the old controversy has died down, it flames up here and there and now and then as smouldering fires will in disconcerting fashion. Many attempts have been made since to settle the issue once for all ; they have all broken down. I do not propose to discuss the consequences of this dual system at any length, for the subject was dealt with ably and faithfully in a recent Presidential Address to this Section.

But three things perhaps I may suggest. Firstly, no settlement is likely to prove permanent which does not give the local authority the right to insist that the best qualified applicants shall be appointed to teach in in the non-provided schools, and secondly does not allow of the employment of any teacher who holds the State certificate in any public elementary school. And thirdly, the present arrangement occasions serious waste of teaching power and of public funds, which last, at any rate, is of great moment in the present state of national finances. It is, I think, unfortunate that the recent Act, enabling the closing of schools which are educationally unnecessary, is crippled by insistence that duality must be maintained as a condition precedent.

But the fundamental change which the Act of 1902 made was the creation of local education authorities charged with responsibility for all forms of education in their areas, namely, the councils in the administrative counties and the county borough councils. In the county boroughs the Act replaced one popularly elected authority by another, though with widely extended powers, for in almost all the county boroughs there had been school boards responsible for a provision of elementary education adequate for the needs of the area, so far as those were not met by the voluntary schools. In the county areas, however, the position was very different. For though the counties have a long administrative history, the popularly elected County Council was a very young body and had hardly got into its stride before these new duties were thrust upon it.

Moreover, and apart from certain powers which the councils exercised under the Technical Instruction Acts, to which I shall refer again, the only previously established education authorities in the county areas were the school boards, which had been let in under Mr. Forster's Act where the voluntary schools were unable to supply sufficient elementary education. These authorities were scattered irregularly in pockets, usually small, over the county areas. Their suppression was locally unpopular. Their members, who generally represented what there was of enlightened educational opinion in their several localities, had to be conciliated, for they were inclined to go into opposition to the new county authority, and beyond that, the County Education Committee and its officers had a sufficiently heavy task in bringing home to the rate-payers that they were now members of a large education area, and in stimulating and focussing appreciation of the educational needs of the area as a whole.

An administrative area for education purposes is not created merely by tying together a number of smaller education authorities, or even by clothing an authority existing for other purposes with educational powers. For effective functioning a common outlook has to be achieved and the will to organise and work together for common purposes must be evoked. It is a slow process which cannot yet be said to be fully accomplished, certainly not in many areas as regards education beyond the secondary stage. This weak position in which the counties were in contrast to the county boroughs, was in part reponsible for a serious departure in the Act from the principle that education is one and that educational administration must be single. I refer, of course, to the Part III authorities responsible for elementary education only. Of these there are about one hundred and seventy boroughs and urban districts—islands for the most part in the areas of the sixty-two English and Welsh counties, and containing not quite a third of the total county populations—islands of all sorts and sizes from little towns of 9,000 and 10,000 to the urban areas round London with populations nearing the second hundred thousand. Many of them are beyond doubt very efficient within their statutory limitations. They have a civic pride in their schools which is not common in the county areas. On the other hand, most of them are too small to form satisfactory administrative units even for elementary education, and generally they are a clog on the development of the national system. The central authority cannot forget them in framing its regulations and settling its administrative precedents, yet reasonable treatment for Little Pedlington may be merely annoying when meted out to a large county or county borough. They cut across county schemes of organisation, and while it is only fair to admit that they desire as a whole to co-operate, they complicate, and therefore add to the expense of administration. Moreover, officers and teachers tend to move to the larger areas, and in the long run the quality of the local education service is injuriously affected.

But the principal reason for removing the anomaly of the Part III authority is that with its existence is bound up the preservation of the statutory distinction between elementary and higher education. It was inevitable that, on the transfer of organised elementary education from the school boards to the new local authorities, the whole apparatus of parlia-

mentary enactment and departmental regulation, including separate rating, should go over into the new régime. There were no beginnings even of organisation in higher education out of which a unified system could be constructed. The distinction, however, always was unreal. Higher education is by statute education other than elementary, which in the absence of a definition of elementary education gets us nowhere. There is no definition of elementary education in any statute, but an elementary school is defined as a school in which the principal part of the instruction is elementary, which recognises the possibility of something more than elementary instruction being given in it. At one time indeed the old Science and Art Department impartially aided the teaching of science in both elementary and secondary schools.

In actual practice, higher and elementary institutions have always overlapped, both as regards the ages of the pupils attending them and as regards the details of the curricula followed. The distinction is purely administrative, serving no useful educational purpose, and the modern development of the division between primary and post-primary has made it not merely useless, but absurd. It is also a nuisance, for it involves debatable apportionments of common expenditure, separate accounting, and other duplicate arrangements. Economy will be promoted in more than one direction by its abolition.

The tide of opinion is setting towards the effacement of the Part III authorities—witness the recent Act which forbade the creation of any more of them as the result of the re-arrangement of local areas under the Local Government Act of 1929. There is already a clause in the Education Act which allows them to surrender their powers to the county council. Need I say that the instances of such surrender are few. If local authorities, educational and other, have a common characteristic, it is the pertinacity with which they cling to the powers they possess. 'What we have we hold' is their motto. Some of the Part III's should be absorbed into the adjacent county area, the larger of them should be vested with full powers. No authorities should be allowed to survive which are unable to support a reasonable number and variety of schools at least to the end of the secondary stage; on which principle some county and possibly some county borough authorities ought to lose their present powers.

The relative positions of the central and the local authorities are very different in the two spheres of elementary and higher education. The Act of 1870 was extremely regulative. The powers, the duties, and the procedure of the school boards were prescribed with great particularity, and the control of the central authority was secured through its minutes, the well-known Code of Regulations for Public Elementary Schools, which, after confirmation by Parliament—an almost nominal proceeding—become the conditions of the payment of parliamentary grant. And the Code was even more detailed than the Statute. There were 130 articles, many of them with sub-sections, in the first Code under the Act of 1902. The school board and their successors were to enter the field of elementary education, but there must be no walking on the grass. It reminds me of a one-time open path which I used to take through beautiful country, but

I go that way no more, for now galvanised netting is high on cither hand for a mile or so, and one arrives at the end in a state of exasperated longing for a pair of wire cutters. Some of you may know that walk and the educational institution which at vast expense has put such a slight on our common ability to behave ourselves.

There are still stretches of the old statutory fencing in the Education Act, although nominally it was all taken down in 1918. The Code of Regulations, however, is far less detailed than it used to be. The 130 articles with sub-sections have shrunk to a reasonable 27. For this comparative freedom local authorities have to thank another predecessor of mine in this Chair, Lord Eustace Percy. Lord Eustace claimed that the Code, as revised in his time at the Board, gives the authorities a wider field for the exercise of their discretion, and the claim can be freely allowed. 'The limit of useful State control is to be found at the point where it ceases to be an expanding and stimulating force and tends to fetter or sterilise.' Those words are quoted from Sir Robert Morant, the architect—if any one man can be so styled—of our present educational system. For fifty years from the time of Robert Lowe's Code of 1862, elementary education moved in fetters, and the marks of that servitude are still upon it ; only gradually is it recovering the vigour, the elasticity, and variety of which a too restrictive control deprived it.

On the other hand, the local authority was given full power from the beginning to supply or aid the supply of higher education as it thought fit after considering the needs of its area and consulting the Board of Education. In theory, the central authority is here a friendly adviser, and can exercise no control so long as the local authority is prepared to finance its own schemes entirely. The friendly adviser, however, in this case is usually ready to back the advice with offers of financial assistance, and although at first in a number of instances authorities were willing to pay the piper for a tune they preferred, there are not many higher institutions left—I do not myself know of any—under local authorities, which the Board does not aid. At the same time, this power the local authorities have of resuming their independence is very real and colours all their relations with the Board. I wish to avoid all suggestion of a reluctance on the part of the Board to give the local authorities their due, or of serious differences of opinion between them, for in fact consultation between the Board and the authorities is frequent and close, and the differences which do occur are in matters of detail rather than of principle. But the position is that of two parties in a negotiation which either of them can break off, one perhaps more easily than the other, and for which each of them desires a successful conclusion.

The administration of the Exchequer grants under regulations framed by the Board is the greatest factor in the relations of the central with the local authorities. By most people these grants are regarded merely as subventions in aid of local expenditure. They are that, but they are also a powerful instrument for the furtherance of national policies and a precise technique has been worked out for so using them. There is not time to develop this point, but an example will illustrate my meaning. I select one which at the present time is agitating the county authorities—an

example of misuse of the instrument. Two of the elements in the formula under which the grants for purposes of elementary education are assessed are the expenditure of the authority on teachers' salaries, of which fifty per cent. is met by grant and administrative expenses, of which the Exchequer finds twenty per cent.

Reorganisation in county areas involves the provision of senior schools at nodal points to which the older children of the surrounding district are transported. The process is attended by some saving in salaries, and within certain limits the larger the school the more economically can it be run. Not only so, the larger school can combine variety in the curriculum with greater uniformity in the classification of the pupils, and in the end should prove the better school. But a larger school means a wider gathering ground and a heavier transport cost. Yet the Board appropriate half the saving in teachers' salaries and leave the authority to bear four-fifths of the heavy cost of transport. The effect of the grant regulations is therefore to dissuade the authorities from plans which are nationally economical and educationally desirable and to reinforce the understandable preference of the countryside for the small and less efficient school near at hand.

This method of giving grants in proportion to expenditure, and at rates varying with the type of service aided, was brought into full operation in education by Mr. Fisher's Act of 1918. Obviously it is designed to encourage expansion and to stimulate authorities to the more adequate discharge of their duties. The argument that the Board bears part of the cost can be very convincing. Though not simple in administration it keeps pace with the growth of institutions, and through the provision of an overriding minimum grant it recognises the importance of the local organisation of schools. Notwithstanding its occasional misuse education committees generally approve it, though perhaps some of them who are chary of expansion and have no wish to be stimulated still hanker after the old method of separate grants on a *per capita* basis for individual institutions.

In the discussions which are raging round education and everything else the method of the percentage grant is challenged on the ground that it lends itself to extravagance and involves a meticulous interference with the business of the authorities, objections which you will observe tend to cancel out, and it is suggested that block grants assessed over an authority's expenditure during a standard year and fixed for a term of years, three, five, or even seven, should be given instead. A block grant has none of that flexibility which enables the percentage grant to be administered in immediate conformity with Governmental policy, out of which no local authority can expect to be allowed to contract itself. Nor can I see why a central department or sub-department, with a policy of its own, should be less disposed to encourage expenditure on the part of a local authority under a block system grant, which defers the day of reckoning, than under a system which automatically obliges it to share the cost. The last report of the Estimates Committee of the House of Commons comes to the support of my contention, for the Committee therein publicly censures the Board of Control for pressing local authorities to incur unnecessary

expenditure and the Board is a department of the Ministry of Health, where the block grant system obtains. Can you even imagine the Board of Education nowadays risking any such rebuke ?

The task to which the new local authorities of 1902 were principally called was the development and organisation of an adequate system of secondary education. It was not a virgin field of which they took possession. There were the endowed grammar schools, mostly of pre-Reformation foundation, individually independent, usually small and struggling to make ends meet on very inadequate resources, some of them too disheartened even to struggle—mere class alternatives to the ordinary elementary school. There were the schools of the companies, and of the religious bodies, not quite so hard pressed, frequently with ends to serve other than those which a public system must ensure. There were the organised science schools—the categories are not mutually exclusive, taking grants from the old Science and Art Department for the teaching of specific subjects. There were the centres for the training and education of pupil teachers provided by the old School Boards, and there were the private schools, good and bad, demanding to be taken into account. Rightly indeed were the authorities enjoined to a careful consideration of the needs of their area before attempting to bring order into this chaos.

The story of the last thirty years in secondary education is absorbing for those of us who lived in it. By strenuous and persistent effort the local authorities have transformed the face of this department of national education in a generation. It would be difficult to instance another movement which achieved as much in as short a time and with so little of that wasteful effervescence which characterises and sometimes mars great outbursts of activity on a national scale. The story cannot be told now ; I can do no more here than mark the line and pace of the development by way of giving substance to the high claim I have made for the authorities.

The Board of Education lost no time in giving a lead. Local authorities might be sceptical about the need for more secondary schools, but they knew that at least the elementary schools must be staffed and that they had to find the teachers. In 1903 new Regulations for the Instruction and Training of Pupil Teachers were issued, in which it was indicated that up to sixteen years of age the intending pupil teacher should be educated in a secondary school. That meant that every boy or girl in the public secondary schools of some areas would be needed for the teaching profession, and the question of increasing facilities was at once brought out of the realm of theory.

A year later came the first Regulations for Secondary Schools, with a definition of the term, very general in form, which has not yet been superseded. In the regulations the length of the course, the subjects of study, even the minimum of time to be devoted to each subject, were all precisely stated. You will look in vain for this last requirement in the regulations of to-day.

Of these two sets of regulations it can, I think, be said that, while in form they were prescriptive, laying down conditions which must be complied with if the Parliamentary grant was to be taken, the underlying

intention was that they should be educative, in the one case formulating for the first time a conception of the secondary school for the guidance of authorities and teachers, in the other suggesting that the function of the secondary school passes beyond the education of the single pupil to the service of the community.

The only other set of regulations which require mention before we consider the evidence of progress in the development of the secondary school system, are the Regulations of 1907, in which the greater part of the 1904 Regulations were included, but which were also further prescriptive in two important respects. In the first place, no new schools could be placed upon the grant list unless the representatives of elected authorities formed the majority of the governing body. This was no doubt intended to be the first step towards bringing all the schools aided by Government grants under local popular control. So far, however, as the local education authorities are concerned, the effect has not been quite what appears to have been expected. The representatives of the popularly elected authorities keep up a useful contact between the aiding authority and the aided school, but in my experience they count for very little in the control which the aiding authority exercises, for they are prone to put the interest of the school they serve first, and the authority which appoints them receives but secondary consideration—a very English and, on the whole, a healthy habit.

The other prescription of the 1907 regulations was of much more consequence. Provision was to be made for the admission in the normal case of 25 per cent. of the new pupils in any year from the public elementary school, free of all school fees, but in every other respect on the same footing as the fee-paying pupils. The percentage stood as an obligatory minimum until the new Special Place Regulations took effect a month or so ago, but as a permissive figure it has been raised first to 40 per cent. and three years ago to 50 per cent.

I shall have something to say in a moment about the practical effect of this regulation. The older among us will remember with what doubt and hesitation it was received by the schools, for as Sir Robert Morant expressed it in another of his early reports, the idea that elementary and secondary schools represent not successive stages of education but alternative kinds of education, meant for different social classes, was deeply rooted. Those doubts vanished long ago: for the free place holder, with few exceptions, readily took on the colour of his new school; on the whole he remained longer and stayed the course better than his fee-paying fellow.

Until the Board and the authorities got down to work it had been commonly assumed that their task would be in the main to bring the existing unorganised and sporadically created secondary schools into an efficient system. The field appeared to be full of resources: what was necessary, was in the words of the Bryce Commission, ' to correlate and harmonise the forces and agencies already at work.' The local authorities very soon discovered gaps which needed filling, but what was not generally foreseen was the tremendous drive for secondary education which an awakened public opinion was about to motive. It was, for

example, at first taken for granted that the new free places would be filled without competition, indeed that they might even go unfilled for lack of qualified applicants.

Let us see what has actually happened. In 1902 the number of schools receiving State aid through the Board was under 300, and the number of pupils taking an approved course under 32,000. Three years later the number of schools had risen to 600 and the pupils to 100,000. By 1911, the last year of Sir Robert Morant's term at the Board, the number of grant-aided schools was 862 and the number of pupils had passed the 150,000 mark, if we include those in schools recognised as efficient but not in receipt of grant.

The first year of the War came and found 205,000 children in the schools. Down to that point the rising tide of numbers from 100,000 to 205,000 in ten years had encouraged authorities and administrators to lay their plans with confidence. The flow was steady as well as strong; there was no falling off in demand to warn us that high water was nearly reached. Was the War that warning? Had we come to the turn? The answer soon came in a thrust for secondary education the like of which this country had never seen before—is hardly likely to see again. In the five years 1915 to 1920 the school numbers leaped with accelerating speed by 113,000. The thrust was not due, as the cynics suggested, to easy money which enabled parents to pay school fees without feeling them much, for in the next year, the year of the first economy wave, there was a further leap of 32,000 and, save for a slight fall of less than 1,000 in 1924, the advance has continued until in 1932 there were 452,000 children, nearly 10·5 per 1,000 of our total population, receiving secondary education in nearly 1,600 schools recognised as efficient, of which the local authorities provide not quite half.

In the discussion of educational problems the layman probably gets less help from the professional than, as paymaster, he is entitled to, not by reason of undue reticence on the part of the professional, for we are a talkative profession, but so much of the talk is about temporalities—pay and pensions, status and prospects—and argument at the top of the voice, in other words shouting one's opponent down, is very fatiguing to the listener. So the layman is driven to reason from his own youthful experiences until he renews his contact with the schools through his children. It is not surprising that the idea that the secondary school is a class school should still linger on. Is there anything in it? Rapid as the growth of the schools has been, the free place holders have increased even more rapidly. In the first year of the century there were about 5,500 children from public elementary schools attending the secondary schools with the help of public funds. By 1906, the year before the Free Place Regulations were made, there were 23,500. Within four years of the passage of the Regulations there were over 49,000 free place holders, and nearly a third of the total numbers in the schools were in this category. At that time one out of every twenty-two elementary school leavers in England went to a secondary school, and one out of every forty-six received free education there. This process of social interfusion has gone on without a check during the twenty years which have since elapsed,

until last year the ex-elementary school child constituted 71 per cent. of the English secondary school population and one in eight of elementary school leavers made his or her way to the secondary school, every other one with a free place. Such figures speak for themselves.

The story of secondary education hitherto, as we have seen, has been one of uninterrupted expansion, but we are at the end of a generation and there are indications that the national impulse behind the movement is faltering, or perhaps making ready to find another channel. The example of Wales, which even now has half as many more children in proportion in its secondary schools as there are in the English schools, stands as a warning to would-be prophets. Nevertheless, I doubt whether many more schools of the secondary type will be founded, and when the population 'bulge' of the first two post-war years ceases to have effect, the tide of numbers may be expected definitely to ebb. What becomes, what has become, of these thousands of pupils, old and new? The parallel extension of State control over, and interference with, the lives and business of its citizens, the creation of new departments of State, the great increase in the Civil Service, both central and local, before the War accounted for many of them. They staff the teaching profession. About sixteen per cent. of them go to the universities and other institutions of higher education. Nearly two-fifths of them enter the minor professions, or become clerks or go into business. Less than fifteen per cent., rather more than a tenth of the whole, enter any kind of industry. But the Civil Services have ceased to multiply, the teaching profession is over-full, and the clerk is being replaced by machines of every sort. The schools have been remarkably faithful throughout to the conception of an education mainly literary, given through a balanced curriculum of subjects mainly traditional. They have turned their pupils almost exclusively in the direction of the academic, the professional, the 'black-coated' occupations.

They are staffed from the academic group in the nation, and while it has ensured high intellectual standards, that fact has enabled them to tolerate the adaptation of their curriculum to the requirements of the universities, until recently, with no sense of discomfort. They are academically controlled, not only in the advanced work which is the prelude to university study for the small fraction of abler pupils, but also through the certificate examinations which are the goal of the average. The irruption of the free place holder has made little difference. The social ideals which underlie the schools' practice are congenial, if anything too congenial, to the poor child and his parents, ambitious that he shall escape the drudgery which they have had to undergo. To them a secondary education stands for advancement in life and the promise has hitherto been realised.

But, as I have already pointed out, the prospects of advancement along the customary lines are not so bright as they were. And another factor needs to be reckoned with. For five-and-twenty years we have been transferring picked boys and girls from the elementary schools to the atmosphere of the secondary school. No wonder industry complains that it is being robbed of its best recruits. The thoughtful employer

agrees that his junior employees are better mannered, more self-respecting, more amenable than those of pre-war days, but he does not find in them the alertness, the resourcefulness, the desire for responsibility which a sufficiently high proportion of their fathers displayed. Yet British industry was probably never more in need of these qualities in its workers than it is to-day.

Is it the business of the secondary school to meet that need of industry ? We have in our organisation proceeded on a theory which, nakedly expressed, appears to be this. We will choose as well as we may, at about the age of eleven, those children who can undergo a further five years of full-time education with profit to the community and to themselves ; they shall go to the secondary school ; the rest shall complete the compulsory elementary school course, and as for any education beyond that, it shall be a voluntary part-time affair. On that theory the secondary school is the common full-time school for adolescents. Can we say that it is performing so comprehensive a service satisfactorily ? Not unless we have the hardihood to maintain that full-time study, extending over the period of adolescence, is only necessary for those who are to enter the academic or professional classes or the public service, or the managerial ranks in industry.

The schools are now finding themselves obliged to go further afield in the search for suitable openings for their pupils, and the contacts they are making in this way will in time react healthily upon their work. There will be a broadening of the curriculum and maybe a less scholastic approach to the more traditional subjects, especially when the grip of the School Certificate examinations is relaxed. But anything in the nature of a general turn over to the American high school type is to be deprecated, though one would like to see that alternative tried out in some of the larger urban areas. The average secondary school is perhaps fortunately lacking in the capacity for so great a change, and were the change forced upon it by authority much that is honourably distinctive would be lost. The high intellectual standards, on which are based not merely the after competence of the professional classes, but the whole leadership of the nation, would certainly be impaired. If, however, the secondary school is to be left unaltered, save for developments from within, to continue its present contribution to the national life, there will need to be a reduction in the number of its pupils for at least two reasons.

We are admitting to the schools to-day children who are unequal to the curriculum, and whose motive for attempting it is mainly social ambition. As Sir Michael Sadler, another former President of this Section, pointed out years ago, ' it is possible to over-stimulate the intellectual susceptibility of people of mediocre talent without adding much to the sound stock of critical or practical judgment possessed by the nation '—a form of waste, he went on to add, ' which we are distinctly in danger of incurring ' : a form of waste which we must confess is actually being incurred. There are also children of another type in the secondary schools, not necessarily inferior, who would be better suited by a less academic and more practical curriculum. If these two groups are to be turned back, the senior school, the modern school of the Hadow Report,

will have to receive them for the present. About the part these modern schools will play in English education, I hope to say something later. I believe that they will very shortly attract in large measure that public interest and support without which no type of school can grow freely in our soil. Whether they will develop to any large extent courses for industry and commerce, between say the ages of fifteen and eighteen, and at the end of the general course, or whether these courses will be provided in association with the technical schools as a kind of high school accommodated in technical institute buildings, as some of the old organised science schools used to be, is a question for the future. I shall have to point out presently that outside the secondary school there is very little evidence of a demand for voluntary full-time education after the compulsory age is reached, so that any development of such education towards industry and commerce is bound to be gradual.

The inquirer approaching the subject of instruction for industry and commerce cannot fail to be struck by the unsystematic—almost haphazard—manner in which facilities appear to be disposed. It is only in a few large and highly industrialised areas that one finds evidence of constructive planning. Over a large part of the country the field is occupied, though not covered, by a medley of institutions which often have little relation one to another. The local school of art will probably have no connection with the technical college : as likely as not the commercial school or department will be quite independent of the industrial departments of the college ; yet surely design has an important place in industry, and what is commerce essentially but the exchange of the products of industry ? Again, the institutions themselves overlap to a surprising extent. The official titles—technical school, technical college, evening institute, and so on—afford no certain clue to the range and standard of the instruction which is given in them.

This state of affairs is partly an inheritance from the early nineties of last century, when the nation was aroused chiefly by the extraordinary expansion of German trade, though the reports of Commissions and Committees played their part in the awakening, to the need for more and better commercial and technical training, and insisted that something must be done. Under the national impetus technical instruction made a fresh start. The municipalities and the counties were constituted authorities by the Technical Instruction Act of 1889, with rating powers, and were encouraged to get to work by Exchequer grants of nearly a million pounds out of the Local Taxation (Customs and Excise) Account, popularly known as the whiskey money, which were applied to this purpose as an afterthought on the part of Parliament. Many of the municipalities hastened to erect technical colleges, sometimes with no very precise ideas about the character and extent of the instruction which they were going to provide, enthusiasm usurping the place of a careful survey of existing provision and of local needs.

The present confusing position is also in part a consequence of the lines on which our educational system is organised. In most continental countries technical instruction is a function of the State, and can be planned on a national basis, or at least on the basis of large provinces

whose inhabitants earn their livelihood in groups of connected industries. But in this country the local education authorities are primarily responsible for providing technical and other forms of instruction. There are a few instances of localised industries whose boundaries coincide, or nearly so, with local authority areas, and in those areas systematic planning has led to satisfactory results. But industry as a rule has no respect for administrative boundaries. In consequence, the attempt to provide for the needs of an area without reference to what neighbouring authorities are doing usually involves some waste of resources, as well as a loss of efficiency, particularly in the higher branches of instruction, by which only a select few have the capacity to profit.

The situation calls for regional planning as the next step in the organisation of higher technical education. A beginning has been made by groups of authorities, notably in the West Riding of Yorkshire and in south Lancashire. In others progress is impeded by causes which I have mentioned earlier in this address. It will not be easy gradually to transform the local authority colleges into groups of co-ordinated regional institutions. In some of the regions the Board of Education will probably in the end have to give a strong official lead, instead of depending, as they appear to do at present, upon the tactful and unofficial ministrations of their inspectors and other servants.

The public interest displayed in the late eighties and nineties in the new movement for technical instruction soon waned, for the early results were disappointing. It had to be realised that technical education is not self-sufficient, and cannot be successfully provided in the air, so to speak. To be of value to the individual and to the community it must build on a sound foundation of general education, and the successful completion of the elementary school course, gravely deficient as it then was in the element of science, was not such a foundation. When this was understood, the more thoughtful authorities began to give attention and to divert some of their funds to the encouragement of the teaching of science and other subjects which were more cultural than technical, and to the transfer of the brighter elementary school scholars to the secondary schools. Their activities in these directions paved the way to some extent for the renascence of secondary education which I have already discussed. It was not until the Great War was over that industry and commerce began to ask on any considerable scale, and apart from isolated instances, for the help of the schools in meeting the great changes brought about by the application of new scientific discoveries to manufacturing processes, and by the invasions of the machine in every department of work. Industry and commerce are still busily discussing their requirements and endeavouring to formulate their demands upon the schools. As regards industry, at least, the discussions can hardly yet be said to have issued in any very clear conclusions. To borrow the language of the theatre, what the educationist hears for the most part are 'confused noises without.' So long as industry is obliged to make its comments 'off stage' one can hardly expect anything else.

At this time of day it is unnecessary to stress the argument for a close association between the industrialist and the educationist in the business

of technical instruction. The need is admitted, though there is here and there some lingering reluctance to set about devising methods for meeting it. The method officially favoured is the advisory committee of manufacturers and employees. My own experience in connection with the boot and shoe industry, however, leads me to advocate the direct representation of the manufacturing interest on the management committee of the institution or department. There is the same time-lag in the manufacturer's notion of what the schools are doing, the existence of which in the mind of the general public I have already referred to. That time-lag is quickly recovered where there is immediate contact with the institution itself. Not only does responsibility put a keener edge on service of any kind, but advice is tendered more carefully and is generally more practicable where that responsibility exists. The typical manufacturer is accustomed to see to the carrying out of his own ideas ; he does not take kindly to sitting in another room and framing recommendations which a committee of management can ignore if it chooses, and is sometimes even disposed to regard as critical of its own action, or more usually inaction. For there is a type of public man which has a great capacity for deluding itself into the belief that popular election at once endows the elected representative with knowledge adequate for the performance of any public duty. Therefore let the manufacturers and employees have their representation on the governing body of the technical school or college, sharing in the give and take of its discussions, and in its responsibility for the conduct of the school. The ultimate power of the purse can easily be retained for the local authority by requiring an annual estimate of expenditure classified under appropriate headings, which when approved, must not be exceeded without going through the process of the supplementary estimate.

Technical education in this country rests upon a voluntary basis. As I have shown, it owes little to suggestion or consistent stimulation from above. The old term ' further education ' would be a better description of it, for the desire to ' get on ' and prosper is only part of the story. Its chief motive force still is the craving of the individual for self-improvement. The youth of ordinary elementary education, on whom it dawns at about eighteen or nineteen years of age that his prospects of economic advancement are small, bestirs himself to take advantage of it. But there are numbers of students who want to develop particular studies for their own sake, and again others who are not content to accept the riddle of this unintelligible world, which every man becomes aware of sooner or later, without making an effort to unravel it. These conditions explain why further education is so largely part-time education. They also explain the great number of students to be found in the part-time classes and institutions of all kinds. There are now about a million of these students, of whom perhaps 50,000 are studying in their employers' time, or partly so, during the day, and the rest are attending night schools in their own time. Contrast that figure of a million with the number of those who are engaged in pre-employment full-time vocational courses. There are hardly more than 30,000 of them. If we examine the position at the critical age of fifteen to sixteen years we find that there are no more

than 1,000 in full-time technical college courses and day technical classes, and another 1,000 in full-time art courses, junior and senior, while there are about 6,500 in junior technical schools. Finally, bring into the comparison the 63,500 adolescents of the same age in the secondary schools and the remnant of 16,500 who are in the elementary schools. Even when allowance is made for the fact that practically all the elementary school remnant, and rather more than 7,000 of the secondary pupils aged fifteen to sixteen, will eventually find their way into industry, the volume of full-time pre-employment education of any kind for industry appears painfully small.

The administrator or the teacher can do very little to make good the deficiency. As Mr. Ramsbotham said the other day, 'the course of education is primarily governed by its social surroundings, by the thoughts and actions, the needs and aspirations of adult society, and not by the desires or ideals of educationists.' The regional co-ordination of schools, even the association of industrialists with their work, will not of themselves create a demand. What is lacking is a conviction on the part of adult society that this form of instruction is a necessary element of our national well being. The nation must will to have it so, and as yet there are few signs, apart from the vociferation of interested parties, that the nation is not quite content to have it otherwise.

In our development of technical education on a part-time basis for those already in employment we differ from continental countries, where in the main technical instruction is conceived to be a full time pre-employment training. We differ from them also in another important respect. While we recognise that there must be grades of employees, workmen, charge hands, foremen, departmental managers and so on, neither the educationist nor the typical industrialist agrees that you can conclusively predict beforehand the grade in which the recruit will ultimately come to rest. There are too many examples of men in high position who owe their success to their character, their temperament, and their capacity, rather than to any specialised training they have picked up on the way, for us easily to accept the theory of the stratification of labour which lies behind the graded schools of the Continent. It has been said that the process of horizontal stratification into classes which will leave the individual little opportunity for advancement has begun in this country, and that the division of the nation's youth into those who are and those who are not to receive a secondary education is a new social phenomenon whose consequences will be very far-reaching. But there are, and for a long time to come there probably will be, many ways of obtaining a secondary education without passing through the gate of the annual schools examination.

It is repugnant to our national thought and practice that an insuperable line should be drawn through Society at any age. So it comes about that at every stage in our educational system we busy ourselves on behalf of those who have not followed the orthodox routes, that they may have an opportunity of making up what they have lost. We even play with the idea that loss may be converted into gain, the competitors turning up at the starting post for the next stage of the race with certain advantages

derived from the very independence of the line they have taken to get there. We may yet come to the drawing of lines and the erection of fences dividing the people, but if we do the educationist, I fancy, will be the last person whom the community will choose for the job.

I have already indicated that the number of young people who voluntarily avail themselves of the evening institutes and other forms of part-time education reaches a substantial total, but for every one who does so there are at least three whose official education ceases when they leave the elementary school at fourteen. It is often suggested that this is a point at which the principle of compulsion should be introduced into a hitherto voluntary system. The compulsory continuation school clauses of the Fisher Act have been on the statute books for fifteen years. They would secure that every employed young person received instruction in the employer's time for the equivalent of one day a week between the ages of fourteen and sixteen and later between sixteen and eighteen. Why not put them into force ? For a short time they were applied in London, but the enforcement broke down because London draws so much of its juvenile labour from contiguous areas to which the clauses were not applied. There is still one day continuation school under Mr. Fisher's scheme which owes its success largely to the consistent support of the local employers. For the rest the clauses are a dead letter. They are, I fear, destined to remain so for a long time to come. Their general enforcement would be a very costly matter. It was calculated in 1919 that a complete system would require at the end of the third year no less than 32,000 teachers. Enforcement by areas would only be less costly on the assumption that some areas would not enforce, and the London experience goes to show that enforcement on that assumption is impracticable. For enforcement by industries, which is a conceivable alternative in some industries, Mr. Fisher's Act did not provide.

We are told that the nation is already spending upon the social services the utmost it can afford under present conditions. It may be so, though apparently the indulgence of a taste for expensive town halls is of no social service and is, therefore, permissible. At any rate in a time in which education is only allowed to expand at the price of making countervailing economies elsewhere, on the principle of the Irishman's blanket, which you remember he lengthened by cutting a piece off the bottom and sewing it on the top, the day continuation school can be no more than a day dream. Moreover, when funds again become available, the raising of the school age has the first claim. We are too far committed to that by the adoption of the Hadow policy of senior schools to draw back. We may regret that it should be so and that the case for the continuation schools has never been properly put to the nation for decision. Indisputably the transition from school to industry is the most critical operation in adolescent life. Is it not far more important for society that so bewildering a change of outlook and environment should be explained and related to the adolescent's previous experience, that he should be guided and steadied through the first years of independence by teachers who themselves have a knowledge of industrial conditions, than that the

transition should be deferred in favour of one more year of full-time schooling ?

But if we cannot have what we would like, let us try to make the best of what we have. It is a solid gain that the young employee's efforts to improve himself in the evening school are no longer regarded by employers in general as entirely his own affair. Fees are paid by employers, prizes are offered, reports are called for, and are sometimes allowed to influence wages and promotion ; and interest is shown in many other ways. These are all good in themselves, but a time-off system, such as already obtains, for example, in the large engineering centres, would be better than all of them put together. Is it treating education seriously to relegate it, as we do, to the hours which should be hours of leisure after the day's work is done ? The youth of lively and independent mind is repelled by such an arrangement. The standard and quality of the work are alike depressed. It is notorious that irregularities of attendance occur which no other educational institution would condone. Better work is done in the evenings than we have any right to expect, for youth will be served whatever the conditions. But until the classes can be held in the day, the employer finding his share of the time required, there is no prospect of any further large development of part-time education.

The nearest approach which has been made in this country to the type of school with a strictly vocational outlook, but so far comparable in other respects with the secondary school that it can reasonably be regarded as alternative to it, is the junior technical school, which has been officially recognised for about twenty years, though there was much earlier experiment. At the present time there are about 170 of these schools, with about 20,000 pupils between them. They recruit these students at thirteen or fourteen years of age for a three or four years' course of full-time education, with the object of preparing them for entry into industry. Sometimes they prepare for a single local trade, but usually for a group of allied trades. Their success—and they have been very successful—is conditioned by their ability to place their students advantageously at the end of the course, for enrolment is voluntary, and parents and pupils naturally expect some return for the deferment of employment which the course involves. Their association with industry is, therefore, bound to be close, and for the same reason they have individually no latent possibility of indefinite expansion. They are ill suited to the conditions of recruitment and employment in some industries—for example, agriculture and the iron and steel industry. There should, however, be room for a carefully prepared increase in the number in areas where industries predominate, to which the junior technical school is an appropriate introduction.

Their position in the educational system is a little anomalous, for the age of entry does not synchronise with the leaving age in the elementary schools, and falling as it does in the middle of the secondary school course, they tend to lose the children who are recruited by the secondary schools a year or two earlier, for some of whom the junior technical course would be more suitable. To overcome this difficulty it has been proposed that the junior technical school should be made a complete alternative to the

secondary school, recruiting its students at eleven for a five or six years' course, the first two years of which would be devoted to their general education. I doubt, however, whether this would advantage the schools. With the choice between the secondary school and the technical school before them, most parents would elect for the secondary school, and not for social reasons only. It is too early to decide at eleven years of age that a boy or girl is to enter one of a group of trades at sixteen or seventeen. Even if the object were realised, one would anticipate a large increase later on in the number of misfits, and some weakening of the vocational purpose, confused, as it would be, by the need to give a general course to the younger pupils.

Meanwhile, the schools are experiencing no difficulty in getting pupils: rather they are threatened with a different danger, for they have been so successful that in many of them recruitment becomes a matter of selection among applicants, and is decided by competitive tests, which as at present conducted are no certain guide to the comparative ability of the applicants to profit by the instruction given. On the other hand, self-selection by the pupil is no certain guide either.

I can offer no solution of this very interesting little problem. It is interesting because we are here within sight of one of the fundamental difficulties which the fashionable modern doctrine of the planned society encounters. By whom in such a society, and on what principles, are the allocations of man-power to be made, and how, if at all, can they be reconciled with the preservation of that freedom to strive for advancement which I have already spoken of as one of the ideals of democracy? Hitherto we have not been much troubled in education with this aspect of planning, for the junior technical school is unique among our institutions in the deliberate equation of supply to demand. But we are likely to hear a good deal more about it in the immediate future unless economic conditions alter substantially for the better. Although we may not believe that education can be reorganised on the quota system, so many and no more being trained to be clerks, so many to be machinists, and so on, yet I think this feature of the junior technical school is well worth retaining for the sake of the light which will be thrown on the bigger question by the working out of the equation on a small scale.

This discussion of the organisation of pre-employment vocational education, fragmentary though it is, should not conclude without some reference to the effects which the reorganisation of elementary education at the age of eleven into primary and post-primary stages is likely to have. This reorganisation is well on the way to accomplishment in the urban areas. In the country areas there are special difficulties, due in the main to sparseness of population, which it will take years to overcome.

While it is too early to speak positively of the results of reorganisation, certain tendencies can already be discerned. It is much that we are getting rid of the confusion of aim between primary and post-primary, to which was traceable the general feebleness and failure to grip the minds of their pupils, which was found in many of the old mixed schools. The junior school can now apply itself unhindered to the business of the primary stage—development of the ability to communicate with others through

reading, writing and speech: the active exploration of the material environment, including drawing and handwork: the formation of ideas of magnitudes of all kinds and the application of the ideas of number to their expression. The little country junior school, in particular, freed from the incubus of the handful of older scholars who could be such a nuisance to themselves and their teachers, is going to be a happier and more efficient place. Singleness of purpose promotes earlier accomplishment; there is good reason to hope that in this respect a year at least of school life may be saved, and that the curriculum on which not so very long ago the elementary school child was released at thirteen years of age may be effectively completed by the average child of eleven to twelve.

In the new senior school, taking children of eleven to fourteen and fifteen, the most conspicuous feature is the break with the old bookish tradition of elementary education. From a third to a half of the school time is given over to practical work—science, experimentally studied, including domestic science, woodwork and metal work, and many handicrafts. It is commonly postulated that there shall be no vocational bias in this practical work, not even in the later years. At the same time, the children, in the words of the Hadow Report, are to be 'encouraged to take an interest in local industries and occupations, and illustrations for teaching in the several branches of the curriculum should be drawn, where possible, from local examples.'

Allow me for a moment to follow the argument whither it leads. In what way that is educationally profitable, and not merely superficial, can we interest the older children in local industries and occupations? In the case of the modern mass industry, I suggest that at least one way is to explain to them the fundamental process or processes on which the industry depends, and to allow them where possible to try their hand at them. For example, the boot and shoe industry, which is staple in the area in which we meet and the area from which I come, is a mass-production industry.

In shoemaking the fundamental process is the attachment of the upper to the sole, in the case of the welted shoe by means of stitching mediated by the welt and the insole. If that is explained to the children as a process of development in time which is not yet completed, and if they are allowed, under expert guidance, to try their hand in simple materials at this and the immediately connected operations of the original handsewn work as practised before the days of machinery, an intelligent interest in that particular local industry will have been aroused, and the educational effect will extend beyond those of them who know that this is the industry which they will take up when they leave school. But what you will in fact have done is to put the children through the first lessons which the lad who is entering the industry takes in the department of boot and shoe technology at the local technical college or in the monotechnic. Teachers are prone to be too gingerly in the use they make of vocation in the schools. Academically minded people with no personal experience of industry or commerce assume an opposition between education through vocation and general education: the one they say tends to dwarf the growing mind and to narrow the outlook, as against the liberalising, expanding influences

of the other. In practice, as my example, I hope, has indicated, there need be no sharp opposition : indeed all education should have its vocational side, for if on the other hand it seeks to create in the pupil an understanding of his surroundings, on the other it endeavours to give him the appropriate power of using them for his own purposes. The real trouble is that we are very short of teachers of the right kind, by which I mean persons trained to teach who also have an industrial vocation in their fingers.

Vocational bias or no, the senior schools bid fair to endow their pupils with a craft skill, besides other things, for which later they will demand an outlet. In the nature of the case they will find that outlet in local industry. While I am far from wishing to suggest that these practical developments in the senior school will dispense us from the necessity of establishing junior technical schools, where conditions are suitable, I do draw the conclusion that if, by the interaction of the junior and senior schools, the general level of intelligence is being raised—and it is—and if in the senior school the skill of the individual is being trained to a high pitch—and again it is—the senior school will make a very substantial direct contribution toward the training of the rank and file of our industries. As one Trade Union leader expressed it, ' Industry to-day is worthy of a better workman.' Many industries are going to get him, chiefly through the agency of these senior schools.

Practically all the students in the technical classes and institutions of every kind are either in employment or are reasonably assured of employment when they are ready for it. But for a large section of the juvenile population no such comforting prediction can be made. The national conscience is troubled about the problem of adult unemployment. It is no longer enough that the State should provide the unemployed with the bare wherewithal to keep body and soul together. Voluntary agencies are springing up to help the unemployed men and women to maintain their self-respect and to keep healthy in mind and body. But the nation is not yet fully alive to the magnitude of the problem of juvenile unemployment and to its terrible consequences. Is there any worse example of social waste than that the young boy and girl should be carefully nurtured for good citizenship and then plunged without warning into a world in which they find they are not wanted, in which their instinct to be independent is thwarted and the opportunity of honest useful work is denied them ? Could they have any experience more destructive of mental and moral fibre—in a word, more decivilising ? Yet this is the daily experience of thousands of them.

According to the latest figures which are available (May, 1933), 108,000 young people between the ages of fourteen and eighteen were registered with the Ministry of Labour as unemployed though desiring employment. Bad as they are these figures do not tell the worst. Registration at the Employment Exchange is voluntary between the ages of fourteen and sixteen, and if allowance be made on that account there are probably not less than 160,000 young people unemployed. The number has more than doubled in the last quinquennium, and it is likely to increase, for owing to the high birth-rate of the two post-war years there will be an

increase in the number of boys and girls leaving the elementary schools next year of something like 50 per cent. over the number who have left, or are leaving, during 1933, and for the same reason the number of juveniles between fourteen and eighteen years of age available for employment will continue to grow for another five years. The Churches, the juvenile organisations, and other agencies are making great efforts to cope with the evils resulting from this mass of unemployment. The contribution of the State, however, is so small as to verge on the insignificant. The Minister of Labour took credit recently for an increase from £110,000 last year to £150,000 this year in his expenditure upon courses of instruction for unemployed juveniles. Even so, the percentage of the registered and insured unemployed juveniles who were regularly in attendance at these courses was less than twenty-three, and the percentage of those registered and uninsured was only ten.

This state of things increases one's regret that the Continuation School Clauses of Mr. Fisher's Act have not been put into force. The Unemployment Insurance Act of 1930 empowered the Minister for Labour, after consultation with the Board of Education, and subject to regulations approved by the Treasury, to arrange with local education authorities for the provision of courses of instruction for insured contributors under the age of eighteen, and to require attendance at such courses, where they are available, as a condition of the payment of unemployment benefit to any young person. These are the courses which I have just mentioned. As there are less than one hundred of them, however, in the whole of Great Britain, a very large fraction of the juvenile unemployed are beyond their reach. There are in addition arrangements whereby the juvenile unemployed can be sent to the ordinary evening institutes. In May, which, of course, is not a typical month in this respect, less then 200 juveniles had that advantage.

It is not easy to suggest even the lines of a comprehensive scheme for bringing these young people under official educational guidance, for the incidence of the condition varies greatly from area to area. In some areas the numbers are such that separate centres are economically feasible : in others, juvenile unemployment is almost non-existent. But some steps could be taken, given the support of public opinion.

In the first place, boys and girls should be encouraged, subject to reasonable age limits, to remain at school until situations can be found for them.

In the second place, the recommendation of the recent Royal Commission that the age of entry into unemployment insurance be lowered to fourteen should be enacted, subject to credit being given against the Unemployment Fund in respect of voluntary attendance at school beyond that age. This proposal has in the past encountered the opposition of teachers and administrators who fear the effect that the possibility of entry into employment with insurance may have upon school attendance beyond the minimum insurable age. But under the safeguard mentioned, the inclination to seek employment at the earliest possible age will be weakened, and in any case the position is, I submit, too serious to warrant the continuance of opposition on educational grounds.

In the third place, the responsibility for framing schemes for dealing with their own unemployed juveniles should be thrown upon the local education authorities. The Board of Education since Mr. Fisher's Act has had the power to require the authorities to submit schemes providing for the progressive development and comprehensive organisation of education in their several areas. The scheme procedure is, therefore, familiar both to the Board and to the authorities. When the schemes have been submitted to, and approved by, the Board, it will become the authorities' duty to carry them out. The change would involve the transfer to the Board of Education of the administration of all Exchequer grants in aid of juvenile unemployment schemes, subject to such conditions as the Minister of Labour might think fit to impose. The procedure suggested is on all fours with that which is followed in the medical inspection and treatment service. The local responsibility for that service is cast upon the education authorities : at the centre the Minister of Health is responsible, the Board of Education acting as his agents directly in contact with the authorities.

The training of the unemployed juvenile is strictly an educational matter. The Ministry of Labour was established for quite other purposes. It is responsible for the disbursement of millions of money to individuals, and the method of check and counter-check, which in the public interest it is bound to adopt, leaves no room for that play of local initiative which is a characteristic feature of the relations subsisting between the Board of Education and the local education authorities. The problem cannot be dealt with properly on the somewhat rigid lines to which the Ministry is habituated, for it varies from area to area. The Board of Education's administration, on the other hand, is flexible, and the local authorities are accustomed to it. They would be encouraged by the change and would be put upon their mettle. But the essential condition of progress in this, as in all educational business, is an enlightened public interest. A society awake to the degrading influence which enforced idleness is having upon this large section of its citizens-to-be could not tolerate a half-hearted parsimonious handling of so grave an evil.

SECTION M.—AGRICULTURE.

CHEMISTRY AND AGRICULTURE

ADDRESS BY

DR. ALEXANDER LAUDER,

PRESIDENT OF THE SECTION.

A RECENT President of this Section referred in his presidential address to the fact that while many of his predecessors in this chair had been chemists, none of them in recent years had taken the relation of chemistry to agriculture as the subject of his address. A glance at the subjects of the addresses for the past twenty years shows that the presidents who have been chemists have confined themselves to general agricultural questions or to problems of agricultural education or research. It is true that in his address at Toronto in 1924 Sir John Russell dealt with 'Present Day Problems in Crop Production,' and in his masterly survey of the progress of agriculture during the past century, delivered at the Centenary Meeting of the Association in 1931, he surveyed the development of agricultural chemistry during the century, the treatment in both cases being necessarily general.

The importance of the application of science, particularly of chemistry, to agricultural practice has been realised for a very long time. In his address to the first meeting of this Section at Dundee in 1912, Sir Thomas Middleton dealt with this aspect of the subject (' Early Associations for Promoting Agriculture and for Improving the Improver '). So far as the British Association is concerned, this importance, as we shall see later, was early realised. As far back as 1839, a petition to which many influential names were attached was presented to the General Committee asking for the formation of a separate Section for Agriculture. The proposal was rejected however, and for many years there was no direct representation of agriculture ; more recently, a Subsection for Agriculture was formed which was attached either to Chemistry or Botany, and the present Section was definitely established in 1912.

When the Association last met in Leicester in 1907, agriculture was represented by two papers presented to the Chemical Section. One was a discussion on the qualities of wheat and flour, dealing particularly with the strength of flour, and the second on the 'Production of Acid or Alkaline Reactions in the Soil by Manures,' by Mr. A. D. Hall. A glance at the recent programmes of this Section will give some idea of the developments which have taken place since we last visited Leicester.

At the meeting of the Association in Swansea in 1880 Sir J. H. Gilbert was President of the Chemical Section, and devoted his address to the application of chemistry to agriculture. He pointed out that not only was the

application of chemistry to agriculture included in the title of the Section, but that in 1837 the Committee of the Section had requested the late Baron Liebig to prepare a report on the condition of organic chemistry. The first part of his report, entitled ' Organic Chemistry in its Applications to Agriculture and Physiology,' was presented in 1840, and the second part on ' Animal Chemistry or Organic Chemistry in its Application to Physiology and Pathology ' followed in 1842. It is not necessary for me to refer to the far-reaching effects of these reports. As Sir John Russell said in his Centenary address, they can ' without exaggeration be described as the most important publication in the whole history of agricultural science.' Sir John Gilbert went on to point out that in the forty years which had elapsed since the publication of Liebig's reports, no president had taken agricultural chemistry as the subject of his address, and, as I have already pointed out, the subject has generally been avoided during the succeeding fifty years.

Gilbert devoted about a third of his address to an historical introduction and to a detailed description of the new views brought forward by Liebig. He then went on to discuss how far Liebig's views had been modified in the course of time, and to state the conclusions which had been arrived at by recent work on plant and animal nutrition.

As regards plant nutrition, the main problems were the sources of carbon and nitrogen, and the views then expressed by Gilbert are still held without serious modification at the present day. He confirmed the opinion of De Saussure and Liebig, that the greater part, if not the whole of the carbon, was derived from the carbon dioxide of the air. It is worthy of note in passing that he was greatly interested in the effect of continuous daylight on the carbon assimilation of plants and also of the effect of illumination by electric light, but concluded as regards the latter that the determining factor was the cost, which is still the position at the present day.

He then turns to the difficult question of the nitrogen supply of plants and describes the results obtained at Rothamsted by Lawes and himself. The careful experimental work led to no conclusive results. Summing up the result of the inquiry, Gilbert says that ' although the recorded evidence is admittedly very conflicting, we then came to the conclusion, and still adhere to it, that the balance of the direct experimental evidence on the point is decidedly against the supposition of the assimilation of free nitrogen by plants. Indeed, the strongest argument that we know of in its favour is that some such explanation is wanted.'

The explanation followed some six years later, when the memorable results of the Hellriegel and Wilfarth investigations were published.

In the later part of his address, he dealt with two questions which were then exciting much attention, viz. the origin of muscular power and the sources of fat in the animal body.

The conclusion arrived at was that the fat of the herbivora is largely produced from the carbohydrates of their ration. As regards the origin of muscular power, he concluded after a careful review, ' that all the experimental evidence at command tended to show that by an increased exercise of muscular power there was, with increased requirement for

respirable material, probably no increased production and voidance of urea, unless owing to excess of nitrogenous matter in the food or of a deficiency of non-nitrogenous matter, the nitrogenous constituents of the body were drawn upon in an abnormal degree for the supply of respirable material.'

He concluded his address by stating that ' while much remained to be done both in chemistry and physiology as regards the above problems, yet I think we may congratulate ourselves on the re-establishment of the true faith in regard to them, so far at least as the most important practical points are concerned.'

I have dealt somewhat fully with the state of knowledge of our subject fifty years ago in order that we may appreciate more fully the changes which have taken place since then. A great deal of the investigations during the past half-century have been concerned with the more accurate and detailed working out of the ideas discussed by Gilbert and his contemporaries and the explanation of many points in agricultural practice which had been evolved by centuries of experience by farmers, and while nothing spectacular in the way of change may have resulted, the cumulative effect of the more accurate knowledge about soils, fertilisers, crops and nutrition has undoubtedly been important.

In addition, several discoveries of fundamental importance have been made : the synthetic manufacture of ammonia and nitrates ; the effects of vitamins in animal nutrition ; the theory of base exchange in soils ; and the development of bacteriology, to mention some of the more outstanding only.

Some of these, although they might be described as advances purely from the scientific side, have yet had practical applications of the highest importance. The theory of base exchange in soils, which may be said to have originated in this country with the early work of Way in the fifties of last century and is associated in modern times with the names of Gedroiz, Hissink and Wiegner, has provided an explanation of absorption and exchange phenomena and of soil acidity, and has been successfully applied to the reclamation of alkali soils in Hungary (Von Sigmond) and the Western States of America, as well as in the treatment of land recovered from the sea.

Amongst other notable advances which have had a practical application may also be mentioned the use of sulphur for reducing fungoid attacks on crops and for reducing alkalinity in soils, particularly soils used for growing potatoes, and the study of the functions of elements which occur only in minute quantities in plants, e.g. copper, manganese and boron. The application of modern statistical methods to the interpretation of field experiments and of biological experiments generally, has led to a more accurate appreciation of the experimental errors involved, and of the significance attached to any result.

Since the last meeting in Leicester, very real advances have been made in our knowledge of the chemistry of the proteins, carbohydrates and fats, and of enzymes ; this has led necessarily to a clearer appreciation of the processes concerned in the synthesis of plant products and of animal metabolism.

Among the major problems awaiting solution are the methods by which plants take up their nutrients and the further development of biochemical methods generally.

THE SOIL.

The study of the soil may be approached from two points of view. In the first of these it is regarded as the seat of certain chemical, physical and biological processes which are investigated entirely from the scientific point of view without any reference to agriculture. This has been the method of attack of the Russian school in particular, and the supposition is that when a sufficient body of knowledge has been accumulated in this way, the consideration of the facts obtained may result in practical applications of value to the agriculturist ; it should be emphasised, however, that the approach in the first instance is purely scientific. The interesting volume published a few months ago by Prof. G. W. Robinson of Bangor gives a clear exposition of the methods of this school and of the results which have, so far, been obtained. The other method has been to study the soil as the medium of plant growth, to investigate practical problems as they arise and to have as its definite aim the giving of advice to those engaged in agriculture as to improving their methods of tillage and crop production. It is obvious, of course, that no definite division can be made between the two methods of approach, as is shown by the history of recent developments. In this country, while the former method has been by no means neglected, as witness the large amount of research work carried on at Rothamsted and to a lesser degree elsewhere, it is the latter method which has been in the main officially supported and subsidised by successive governments.

Amongst the scientific methods which have emerged and received considerable prominence and support in recent years is the modern method of soil classification. This, while belonging to the scientific method of investigation, also seeks to justify its existence by the claim that it is of immediate importance to the farmer. The method was first developed in Russia where it was shown as early as 1879 that climate is responsible for the great tracts of similar soil found in that country ; this idea was developed by later workers and more recently by Glinka and others, who recognised some of the limitations of the original method and proposed in place of the earlier zonal type of classification a system based on the effect of climate on the development of the soil profile. Soils were divided into two great groups. In the first were placed the soils in which the profile shows that the external soil-forming processes, especially climate, have predominated ; the second group comprises those soils in which the internal process, i.e. parent material, still predominates. These groups are further subdivided, but the whole system lays special emphasis on the development of the soil profile—that is, the vertical section from the surface soil to the unweathered parent material.

Although soil surveys had been carried out for a considerable time in Europe and the United States, modern soil surveying may be said to date from the first International Soil Congress held at Budapest in 1909. At this meeting Glinka explained the new method of classifying and

mapping soils on a climatic basis, and soil surveys on the new basis were soon begun in a large number of European countries and in the United States. At the International Soil Congress held at Rome in 1924 it was agreed to construct a soil map of Europe, and in 1926 the special committee representative of the different countries concerned met in Hungary to discuss in the field the practical details of the work on which the map was to be based. At a subsequent meeting in Budapest the details of the methods were adjusted, and it was agreed to undertake the construction of a map of the soils of Europe based on as uniform a method of surveying as possible. The 'General Map of the Soils of Europe,' under the editorship of Prof. Stremme, Danzig, was published in 1927. The English text, translated by Dr. W. G. Ogg, of the Macaulay Institute for Soil Research, Aberdeen, was published in 1929 with the aid of a grant from the Department of Agriculture for Scotland. The first edition of the map is on the scale of 1 : 10,000,000, and preparations for a second edition are in progress.

The idea of a soil map of Europe is an ambitious one and the conception is not without its attractiveness. In the present state of our knowledge, however, it appears to many that the plan is possibly premature and that there is a great element of unreality in the results. It is only fair to the editors to say that they fully realise the difficulties of carrying out a survey of this extent on a uniform basis, and admit that the results are imperfect and will require to be modified in various ways. It seems fairly clear, however, that the difficulties of making such a map have been seriously underrated. Few workers in Europe have any extensive knowledge of soils outside their own countries, with the inevitable confusion as regards classification and nomenclature. At home, our soil workers have to be content with spending a few weeks in the field each summer. It is evident, therefore, that the difficulties are great and that the rate of progress must be slow. At the same time, the meetings of workers from different countries at the International Soil Conferences with the resultant exchange of ideas and experiences must be valuable in the development of the subject.

Turning next to the methods employed in surveying, the profile is studied as regards horizons, colour and texture changes, structure, drainage and vegetation. The surface horizons are naturally more extensively studied. As regards the chemistry of the profile, most weight is placed on the ratio of silica to sesquioxides ; other factors examined are the presence and accumulation of salts, including calcium carbonate, and changes in acidity with depth. On the results of these observations, the soil is placed in its appropriate class. In passing, it may be noted that there appears to be a certain reluctance on the part of the advocates of these methods to ascertain by means of carefully conducted field experiments whether some of the differences they are mapping are really significant in practice and whether some of the finer differences which they map, between soils within the same type, have any reality and make any appreciable difference in agricultural practice.

As regards the utility of soil surveys generally, a reasonable case can be made out for the benefits which are likely to follow a careful survey of a new country which is just being developed. The difficulty there, is to

provide the staff and funds so that the survey work is kept ahead of the development.

In a country like this, on the other hand, there is considerable doubt on the part of many as to whether the benefits which are supposed to follow such a survey will ever be realised. The question of suitable crop distribution and association is well established as the result of generations of experience and is not likely to be seriously altered as the result of such an investigation. It is claimed that a soil survey on the scale of 1 inch to the mile would be of great importance in connection with manuring and in the interpretation of the results obtained by the various methods of estimating the available plant nutrients in the soil. Before undertaking a survey of such magnitude, it should be pointed out that such a claim would require to be based on the results of a wider series of accurate field trials than are available at present. At the same time, the importance of survey methods from the purely scientific point of view and also in connection with land reclamation problems should not be overlooked.

What the farmer wishes to know about his soil is whether it is adequately supplied with nitrogen, phosphates and potash, and whether there is sufficient lime present to give a satisfactory soil reaction. These are reasonable questions, but it must be admitted that in the past the task of the agricultural chemist who had to attempt to answer them was by no means easy. Much progress has been made in recent years, and although much still remains to be done, more satisfactory replies can now be given to the farmer's questions than was formerly the case.

With regard to nitrogen, no method exists by which we can judge the requirements of a soil as regards this element ; the fact that most soils respond to dressings of soluble nitrogenous fertilisers is about as far as we can go in the way of prediction.

At the same time, it must be pointed out that considerable progress has been made in the difficult question of the nature of the soil organic matter. The recent work of Page in England, Schmuck in Russia and Waksman in America (S.C.I. *Ann. Rep.*, vol. xvii (1932), p. 461) has shown that the so-called ' humic acids ' are in all probability protein-lignin complexes. Synthetic products of this type have been prepared and agree closely in properties with the humic acids found in soil organic matter.

On the other hand, the lime requirement of a soil can now be given with reasonable accuracy by routine methods which are suitable for use on a large scale. The question as to whether the dressing of lime which is theoretically desirable can be recommended is generally an economic rather than a chemical one.

To determine what the requirements of a soil are with regard to available phosphates and potassium is a more difficult matter. The most that can be aimed at at present is to be able to say whether the soil is well supplied or moderately supplied with these constituents, or is deficient in them.

The difficulties of discriminating between the available and non-available constituents in a soil are obvious. In the first place, the way in which plants take up their nutrients from the soil is still a matter of controversy, and the fact that the soil is a heterogeneous and ever-changing

system of extreme complexity greatly increases the difficulties. The chemical methods generally employed involve the extraction of the soil with water or some dilute solvent and the estimation of the phosphates and potassium which come into solution under standard conditions. When the results can be interpretated in the light of field experiments or experience, they are a very useful guide in advisory work. The fact that the method is an empirical one is a great drawback, but the more serious objection is that the results give a measure of the condition of a soil at a particular time only and obviously cannot apply to its condition at different times throughout the year. There is probably no hard and fast line between the 'non-available' and the 'available' constituents, the one set gradually merging into the other.

These fundamental difficulties have suggested the idea of making use of the plant itself as an index to the available plant nutrients in the soil. Much work from this point of view has been carried out and two methods based on these principles have been in use on the Continent for several years. These are the well-known methods of Mitscherlich and Neubauer. These methods, as well as Wiesemann's modification of Mitscherlich's method, have been very ably and critically reviewed by Dr. R. Stewart in a recent publication of the Imperial Bureau of Soil Science (*Technical Communication* No. 25, 1932).

Mitscherlich's method is based on his claim to have discovered a Law of Plant Growth which is applicable to all plant species ; he claims to have established that the plant yield can be increased by each single growth factor, even when it is not present in minimum, so long as it is not present in maximum. In its original form it was given by Mitscherlich as follows : The increase of crop produced by unit increment of the lacking factor is proportional to the decrement from the maximum. This can be expressed mathematically as follows :

$$\frac{dy}{dx} = C(A - y)$$

where y is the yield, A is the maximum yield and x the growth factor. (It is interesting to observe that this equation is identical with that for a mono-molecular chemical change.)

Mitscherlich developed an elaborate technique for applying his theory to the testing of soils by means of pot experiments. Here again, certain arbitrary assumptions had to be made, e.g. as regards the depth of sampling, the effects of the subsoil and the permeability of the subsoil. These assumptions regarding the sampling factor undoubtedly raise serious difficulties and have been the subject of adverse criticism.

From his estimation of the manurial content of the soil, Mitscherlich then calculates the manurial requirements, the calculation being greatly simplified by the assumption of the constancy of the effect factor, which means that the manurial requirements for any one soil are the same for all crops.

Mitscherlich's method has been subjected to severe criticism, first on his theoretical assumptions, his treatment of his experimental data and the applicability of the Logarithmic Law ; and secondly, on the constancy

of the ' Effect-Factors.' Notwithstanding these criticisms, Mitscherlich had such faith in the usefulness of his method that he has developed stations in different parts of Germany for testing soils by his methods. The Soil-Testing Society in East Prussia had in 1931 no less than five stations and the number of pots in use was 25,000, equivalent to 2,500 soils tested. The original cost of a test was £5–£6, but this has been very much reduced in later years. This is direct evidence, at any rate, of the belief of the practical farmer in the value of the test. It is satisfactory to know that an installation of Mitscherlich pots has been set up at the Macaulay Institute for Soil Research at Aberdeen, and that in addition a large series of field pots have been laid down on different types of soil according to the Mitscherlich plan. It will be interesting to see what agreement is found between the results of the tests and the results obtained by laboratory methods of extraction.

The Neubauer method, on the other hand, depends on the estimation of the nutrient content of the soil by the growth of young seedlings. The method depends on the absorption of phosphates and potassium by plants in the early stages of their growth. By adopting a standard technique, and using rye seedlings as his crop, Neubauer proved that the amount absorbed was constant for a given sample of soil. By using a large number of seedlings and by diluting the soil with sand, he considered that the phosphates and potassium taken up by the seedlings would represent the total available supply of nutrients in the soil. This would give the nutrient content of the soil without any reference to the manurial requirements of a particular crop, the estimation of this being the same problem which is met with in all chemical extraction methods of analysis.

Having determined the root-soluble nutrients in this way, the next problem was to calculate from the figures obtained the manurial requirements of the various crops. To do this he makes two main assumptions—(1) that under the conditions of the test the seedlings absorb the total quantity of available phosphates and potassium, and (2) that crops under field conditions can utilise only a certain fraction of the total amounts present owing to the different conditions of growth. Making the above assumptions and estimating the quantities of phosphates and potassium removed by the various crops, he then calculates the ' limit values ' for the various crops. In order to calculate the amount of fertiliser to be applied to soils showing less than the ' limit values,' he again assumes that only 60 per cent. of the potash applied and 20 to 33 per cent. of the phosphates are availing during the year of application.

Neubauer's method has also been subjected to considerable criticism on the analytical details, the influence of external factors and the determination of the ' limit values.'

The analytical work concerned requires a high degree of accuracy and possibly some of the criticism of the method has been based on results obtained without sufficient care having been taken in the analytical work.

The question of practical interest is how do the results obtained by the two methods agree, and which method is the more reliable as to the manurial requirements of a particular soil and crop ? Neither of these questions is easily answered. It may be said at once that there is a wide

divergence between the figures obtained and yet, applying the different standards of the two methods, it is claimed that there is a good agreement in both cases between the results of field trials and the recommendations of the methods. It should be pointed out that the method of comparison is purely qualitative, i.e. if a deficiency of potassium has been indicated by the test and there is a response to a dressing of potassium salts in the field, this is taken as a case of agreement.

One general difficulty which applies to both methods is that they can be carried out only at institutes specially equipped for the purpose. The Mitscherlich method requires a whole season to carry out the test, while the Neubauer requires much supervision and extreme accuracy in the analytical work. Attempts have therefore been made to devise simpler biochemical methods suitable for the ordinary laboratory use ; of these, two are of special interest.

The Azotobacter Method.—The *Azotobacter chroococcum* is a well-known soil micro-organism which has the power of fixing soil nitrogen, and its use as a method for testing soils was first worked out in Denmark. The organism is very sensitive to acid conditions, and this was used as the basis of a method for measuring the ' lime requirements ' of a soil. This method has been superseded by the more convenient and more accurate physico-chemical methods now employed. In addition to requiring a non-acid medium, the rate of growth of the organism depends also on the supply of phosphates, and later the method was adopted for the estimation of the available phosphates in the soil. The defect of the method is that there is no accurate means of estimating the development of the bacteria and that the results are therefore only qualitative in character.

The Aspergillus Method.—The principle of this method is the same as that described above, but it has the advantage of being more quantitative in character, as it is possible to collect the fungus and weigh it. It was found that under standard conditions the growth of *Aspergillus niger* is proportional to the amounts of available potash and phosphates in the soil.

The mould is grown in a suspension of the soil in a culture solution containing all the constituents necessary for growth except the one being tested for. The mixture is inoculated with the organism and incubated for four to six days. During that time, the mycelium develops and covers the surface of the liquid like a felt. It is then removed, washed, dried and weighed. The estimations are carried out in triplicate or quadruplicate, and the results of a large number of experiments have shown that the standard error is of the order 4 per cent. The particular strain of organism employed and the form in which the nitrogen is supplied are important factors in the success of the determinations.

The method has been worked out by Prof. Niklas and his colleagues at the Agricultural Research Station at Weihenstephen, near Munich, and has also been subjected to a critical examination by Dr. A. M. Smith, Edinburgh, who has tested the method with a variety of Scottish soils, as well as investigating the effect of different sources of nitrogen on the process.

The results obtained by this method have been compared with those obtained by Neubauer's method and have shown on the whole very good

agreement, especially for potassium. The richer the soil as estimated by the Neubauer method, the greater the growth of *Aspergillus*. For phosphates the agreement between the two methods is very good as far as poor soils are concerned, but is only moderately good for the intermediate or richer soils ; one difficulty is that the absorption of phosphates by the fungus is not constant for different types of phosphates.

The Aspergillus method is therefore likely to be valuable in estimating the potassium and phosphate requirements of a soil. The results, as might be expected, are more reliable for potassium than for phosphates, and while not rigidly quantitative, give information as to whether the soil is rich or poor in these constituents. It has the advantage of being rapid and requiring no expensive apparatus (A. M. Smith and R. Coull, *Scot. Journ. Agr.* vol. xv (1932), p. 262).

The whole question of available plant food is necessarily bound up with the complex relationships which exist between plant and soil, and it is unlikely that any simple or single method will be devised to overcome the inherent difficulties of the problem and be generally applicable to different sets of conditions. The admitted lack of agreement obtained with the various methods at present in use is undoubtedly due, to a large extent, to the variety of factors involved, as well as to the fundamental objections which may be raised to any one method. We are still very ignorant of the process of assimilation by the growing plant, and until we have more information on this subject, methods of estimating availability must continue to be largely empirical and the results merely first approximations.

The usual method of approach to the problem has been to study the effect of the soil or plant medium on the plant. In Edinburgh attention has in recent years been directed in the opposite direction—namely, to a study of the effect of the plant on the soil. The alterations to be observed are, of course, small, but by applying methods which might almost be described as analogous to modern micro-methods of analysis, measurable changes can be followed with considerable accuracy. The results which have been obtained are interesting and sometimes rather unexpected, and although it is scarcely to be supposed that they will furnish a complete picture of the relationship between soil and plants, one feels that any contribution to the subject from a new angle may be of value in the study of such a complex problem.

Fertilisers.

Turning next to the progress which has been made in the manufacture and use of fertilisers since the time of Gilbert's address, there are one or two notable dates and achievements to be mentioned.

In 1878 Thomas and Gilbert introduced their new basic process for the manufacture of steel which resulted in the production of basic slag as a by-product. It was a few years before the value of the slag as a source of phosphates for plants was discovered. The importance of the new slag in agriculture was first realised in Germany. The earliest experiments in this country were carried out in England by Wrightson and Munro in 1885, and by A. P. Aitken in Scotland about the same time ; a year or

two later J. J. Dobbie carried out the first experiments with the slag in North Wales.

The now classic experiments laid down by Prof. Somerville in 1896 and carried on and developed by his successors, Sir Thomas Middleton and Prof. Gilchrist, have demonstrated the value of this addition to phosphatic fertilisers and show as the result of twenty-five years' experiments that basic slag is, for certain types of soil, even more valuable than superphosphate. Changes in the modern methods of steel making and the effect of the large amount of scrap iron and steel available in the years succeeding the war brought about a considerable alteration in the composition of the slags produced in this country. About ten years ago, therefore, the Ministry of Agriculture and Fisheries set up a permanent committee on basic slag 'to consider the development and improvement of the manufacture of basic slag and the extension of its use.' This committee has produced a valuable series of reports, the last (tenth) report being published in September 1932. The work of the committee has been, in general, 'to make a detailed study of the agricultural values of the slags now available to farmers and the chemical means by which these values can be expressed.' By means of the old but empirical citric acid test, the slags produced in this country can be divided into two groups—a high-soluble group in which 80 per cent. or more of the phosphoric acid is soluble in 2 per cent. citric acid and a low-soluble group in which less than 40 per cent. is soluble. The experiments in recent years have been carried out with hay, and while no final conclusion can be drawn at this stage, the results indicate that with this crop the high-soluble slag showed, in the first year, a slight superiority over superphosphate and a marked superiority over mineral phosphate and low-soluble basic slag, and there was in addition a considerable improvement in the quality as well as the quantity of the hay obtained from the more active phosphatic fertilisers. The figures obtained for the recovery of phosphoric acid were interesting. For two years, the recovery of phosphoric acid added were superphosphate 12 per cent., high-soluble slag 9 per cent., mineral phosphate 4 per cent. and low-soluble slag 2 per cent.

Pot experiments with barley carried out from 1927 to 1931 gave similar results, the high-soluble slags giving better results even than superphosphate on certain types of soil (e.g. Millstone Grit) and markedly better than the low-soluble slags.

It must always be borne in mind that basic slag is a by-product and that its composition may be altered by changes in the methods of steel manufacture. The need for the work of such a committee is, therefore, obvious and the committee should be continued.

The beneficial effects of mineral phosphates as fertilisers was noticed as far back as 1845. New sources of material and improvements in the methods of grinding have led to a great extension of their use in recent years.

Superphosphate.—Improved methods of manufacture and better sources of raw material have led to a progressive improvement in the quality of this fertiliser. In 1907 the total world production was 7,813,570 metric tons and in 1930 this had been almost exactly doubled (15,582,162

metric tons). There has, of course, been a fall since then, but this is due very largely to the prevailing depression. Formerly, superphosphate was considered an acid manure and its continued use was supposed to deplete the soil of lime and to increase its acidity. A large amount of experimental work has been carried out in recent years, and the result is to show conclusively that the objections to the use of the so-called physiologically acid manures have been the result of misconceptions or possibly even misrepresentations. The use of superphosphate does not generally increase the acidity of the soil.

Nitrogenous Fertilisers.—Attention has already been directed to the far-reaching effects of Leibig's reports to the British Association in 1843 and 1847. In the year 1898 the Association was again to take a prominent part in the development of agriculture. The President that year was Sir William Crookes, who devoted his address to showing that if the rate of increase then assumed of the world's population was correct, the world would be faced with a wheat famine in the not far distant future. He pointed out also the necessity, if we were to increase the production of wheat, of the increased use of ammonium salts and nitrates as fertilisers. As regards nitrogenous fertilisers, he showed that we were living on our capital of combined nitrogen compounds and that there was also the danger of a nitrogen famine to be faced. The remedy he suggested was to devise methods for 'fixing' or bringing into combination the nitrogen of the atmosphere, and he actually sketched methods and estimated costs of effecting this combination by electrical means. As far back as 1784 Cavendish had shown that oxygen and nitrogen could be made to combine under the influence of the electric spark. Many years were to elapse, however, before a practical commercial method was evolved. The earlier methods were electrical in character and were developed in Norway and Italy, where cheap supplies of electrical energy were available. These methods have been more or less superseded, and ammonia is now manufactured by a synthetic method on an enormous scale at the works of the Imperial Chemical Industries, Ltd., at Billingham. The method used is a modification of the Haber-Bosch process. The practical difficulties which had to be faced were great; of these I need only mention the problem of working at pressures of over 200 atmospheres—i.e. over 3,000 lb. per square inch—and at an elevated temperature, to enable you to realise some of the difficulties which had to be overcome. The successful development of the method is certainly one of the greatest triumphs of chemistry and engineering in modern times. By this process, which incidentally dispenses with the use of sulphuric acid, sulphate of ammonia can now be prepared more cheaply than from gas liquor where the ammonia is obtained as a by-product.

By the oxidation of ammonia to nitric acid by means of a suitable catalyst ammonium nitrate can be prepared, and by mixing this with calcium carbonate a valuable fertiliser, known commercially as 'nitro-chalk,' is manufactured.

Concentrated Complete Fertilisers.—One of the most interesting developments of the synthetic ammonia industry has been the manufacture of concentrated complete fertilisers containing nitrogen, phosphates and

potash in suitable proportions and all soluble in water. The basis of these fertilisers is a mono-ammonium phosphate which is made by subjecting finely ground rock phosphate to the action of a mixture of sulphuric acid and ammonium sulphate. This gives directly a solution of mono-ammonium phosphate containing a little ammonium sulphate and calcium sulphate is precipitated. The mono-ammonium phosphate contains 12·2 per cent. nitrogen and 61·7 per cent. phosphoric acid and is thus a highly concentrated fertiliser. By mixing this with ammonium sulphate and a suitable potash salt, a wide range of fertilisers can be obtained. The ingredients are finely ground and then passed to a special incorporator in which they are churned by means of paddles, whilst saturated steam is blown in. In this way, granules are formed which are then dried ; roughly, one ton of such fertilisers supplies as much plant food as two tons of the ordinary mixed fertiliser of similar composition. They possess the obvious advantage of reducing freight and handling charges and cost of distribution to the land ; they are granular in texture and very easy to sow, and they can be stored without risk of deterioration ; further, the constituents are all soluble in water.

Another point claimed in their favour is that they contain little except the three fertilisers, nitrogen, phosphates and potash, while the ordinary fertilisers contain appreciable, and in some cases large, amounts of calcium, sulphur, and other elements. It is possible that in some soils the absence of the additional substances might be a disadvantage, and a careful comparison of the new fertilisers with the old mixed fertilisers will be necessary to show that no disadvantage attends the use of the new compounds over a number of years. Accurate field experiments on a wide variety of soils were carried out in this country in 1930 to compare the relative effects of the concentrated complete fertilisers and of mixtures of sulphate of ammonia, superphosphate and potash giving the same amounts of nitrogen, phosphates and potash. With the three crops examined (oats, potatoes and sugar beet), the concentrated fertilisers gave the same average increases in yield as the equivalent ordinary mixtures. At certain centres, however, the concentrated fertilisers gave better results and at others a poorer yield than the ordinary mixtures. The work is being continued.

It is obvious that if the concentrated fertilisers were used continuously over a number of years, increased attention would require to be given to liming.

Biochemistry.

When we consider the development of organic chemistry during the past century, we see that the earlier workers were much occupied with the investigation of the substances which occur naturally in plants and animals ; although many individual organic substances were known before this time, the modern developments of organic chemistry may be said to date from Wöhler's memorable syntheses of oxalic acid in 1824 and of urea in 1828. While the early organic chemists were much interested in those compounds which occur in plants and in the animal body, the trend of investigation, particularly in this country, then shifted to the investigation of more theoretical questions, e.g. the investigation of radicles,

the theory of substitution and types and the theory of structure. These investigations gave a great impetus to organic synthesis and the number of known carbon compounds increased rapidly. Most of the substances investigated, e.g. the many products obtained from coal tar, had no connection with animal or plant life, and organic chemistry became much more the chemistry of the carbon compounds than that of living organisms. Until the beginning of the present century, the interest in the chemistry of natural products steadily declined, and it is only since then that the development of Bio-chemistry, as we know it now, may be said to have taken place. The monumental work of Emil Fischer on the purines, the simpler carbohydrates, the proteins and the tannins, to which he devoted the greater part of his life, laid the foundations of this new branch of the science. His method for the separation of the amino-acids by first converting them into esters and then separating the esters by fractional distillation under greatly reduced pressure, has been invaluable in the study of this group of substances. By 1906 bio-chemistry as a separate branch of the science may be said to be firmly established, and in that year three journals devoted entirely to bio-chemistry appeared in Britain, the United States and in Germany respectively. The work initiated by Fischer has been carried on by a brilliant band of workers in this and other countries, amongst whom may be mentioned Perkin, Willstätter, Gowland Hopkins, Robinson, Barger, Haworth, Windaus, Wieland, Hans Fischer and Dakin.

It is obvious that the investigation of the chemical changes which take place in a living cell presents difficulties of a very high order. The reactions involved take place in very dilute solution ; the intermediate bodies formed have a very brief existence, being rapidly changed into some further product ; so that, while we may know the initial substances involved and the final product of the reaction, there may be little known as to the various stages in the formation of the final product.

While there have been great advances in our knowledge of the structure of many of the substances found in plants and animals, we still know relatively little about the processes by which they are formed. The various stages in the fundamental process of photo-synthesis have not yet been worked out, although plausible suggestions as to what takes place have not been wanting. We are ignorant of the stages by which amino-acids in plants are formed from nitrates and carbohydrates and little is known of the methods by which carbohydrates are changed into fats and *vice versa*. In the same way, while we have a considerable amount of knowledge as to how the proteins, fat and carbohydrates are broken down in animals, little information is as yet available as to how similar changes are brought about in plants. A notable recent advance is Robinson's theory of the way in which alkaloids are synthesised in plants, which has enabled him not only to predict the constitution of certain alkaloids, but also to effect the synthesis *in vitro* of alkaloids and alkaloid-like substances.

It is interesting to note in passing that where individual instances of katabolism have been worked out, the breakdown does not occur, as a rule, in the manner which the organic chemist would expect. The same is true of the degradation of the amino-acids in the animal body.

In a series of lectures on the amino-acids, proteins and the proteolytic enzymes recently delivered in this country, Prof. Max Bergmann of Dresden describes the recent advances which have been made in our knowledge of the amino-acids and the polypeptides, as well as of the changes brought about by the enzymes which attack them. He shows that for more than thirty years chemists have been endeavouring to discover suitable methods for the synthesis of peptides containing the more complex amino-acids, but that only recently has a general method been developed. It is generally assumed that in the proteins the amino-acids are linked together by condensation of the carboxyl group of one amino-acid with the amino group of the next, a molecule of water being eliminated and an amide or peptide linkage formed ; the ordinary protein molecule is supposed to consist of a large number of such linkages. Bergmann points out that the outstanding problem of modern protein chemistry is to determine the effect of combination in peptide linkage on the different amino-acids, and, secondly, how the nature of the peptide linkage itself is influenced by the character of the amino-acids which take part in its formation.

Investigations along these lines, while yet in an elementary stage, have thrown much light on many of the biological processes, e.g. the transformation of an amino-acid to a fatty acid, the biological degradation of an amino-acid to a keto-acid, and, conversely, the biological synthesis of creatine and many other reactions of the highest importance. Willstätter, Waldschmidt-Leitz and Bergmann and his fellow-workers have also devoted much time to the action of the enzymes which attack proteins and have made significant advances along this line of work. Summing up, Bergmann states : ‘ The key to present day and future protein chemistry lies in the development of new synthetic methods, in the action of enzymes on proteins, and on an extension of the knowledge of protein metabolism both in normal and pathological cases.’

Similar advances in our knowledge of the structure of the carbohydrates have also been made. The work of Purdie and Irvine at St. Andrews and of Haworth and his school at Birmingham, of Staudinger, Zechmister and Mark in Germany and of other workers in the United States has been particularly important in elucidating the structure of these complex bodies.

The structure of the simple sugars and of the di-saccharides has now been more or less worked out. The introduction of the six atom ring formula and the greatly increased use of stereo-chemical methods of exhibiting differences in structure have been important factors in the developments which have been made.

More recently, the constitution of the polysaccharides has been engaging much attention and speculation, and notable advances fall to be recorded both by chemical and by X-ray methods of investigation. The adoption of Haworth's hexagon formula for glucose has led to new interpretations of the experimental evidence bearing on the constitution of these substances. It has been shown by Haworth and his co-workers that the constitution assigned to cellulose rests ultimately on the constitution assigned to the di-saccharide cellobiose and the mutual linking of β-glucopyranose

residues in a chain through positions 1 and 4 of the glucose molecule is the fundamental principle of modern cellulose structure. By purely chemical methods of investigation, they have shown that in some forms the cellulose is a straight chain of limited length containing not more than 100 cellobiose or 200 glucose units.

The question of the size of the cellulose molecule has been attacked by various other methods—by viscosity measurements of cellulose dissolved in Schweizer's reagent or of the acetate or nitrate in organic media (Staudinger), by study of the cleavage products obtained by enzymes and by the X-ray methods of the Braggs and of Mark. The interesting fact emerges that the results obtained by the X-ray investigations of cellulose structure are in such wonderful agreement with the views adopted from chemical methods. Sir William Bragg pointed out in a lecture recently delivered to the Royal Institution that cellulose is the fundamental molecular combination occurring in vegetable growth and that it is pre-eminently the molecule of growth in the vegetable world. The cellulose occurring in plants cannot have the same properties in all directions for growth takes place along definite lines. The fibrous nature of cellulose has long been recognised, as we see by the use which is made of it in spinning threads and ropes which can stand an immense strain in one direction. Bragg's investigations have shown that cellulose is made up of crystals, or crystallites, invisible under the microscope, but capable of detection by X-ray methods. These crystallites are partly oriented, having one direction more or less in common and to this arrangement of the crystallites the peculiar and characteristic properties of cellulose are due. Recent studies by Thiessen have indicated that the structure of the pure cellulose fibre is the same as that of lignified tissue, except that the spacing in the latter is wider to accommodate the lignin. Reference has already been made to the fact that the organic matter of the soil is derived from this lignin complex from which the cellulose has been removed.

It has already been noted that the various stages in the building up of carbohydrates in plants have not yet been satisfactorily explained. At the same time, much work of the highest importance on the composition of the chlorophyll in plants, the active agent in the utilisation of the radiant energy from the sun, has been accomplished during the last twenty years. In 1912 Willstätter and his co-workers at Munich showed that chlorophyll as ordinarily obtained is really a mixture of two substances, chlorophyll *a* ($C_{55}H_{72}O_5N_4Mg$) and chlorophyll *b* ($C_{55}H_{70}O_6N_4Mg$). They also investigated the yellow or reddish-brown pigments, carotene ($C_{40}H_{56}$) and zanthophyll ($C_{40}H_{56}O_2$), which accompany the chlorophylls and which are generally referred to as the carotinoids. By a series of brilliantly conceived investigations, Willstätter has been able to throw much light on the structure of these complicated bodies and, in particular, on the relation between the chlorophyll of plants and the hæmoglobin of blood. In this connection reference must be made to the work of Hans Fischer who has already synthesised hæmin and made great advances towards the synthesis of chlorophyll.

Enzyme Action.—It has long been known that enzyme action plays a

highly important part in most of the chemical reactions taking place in plants and animals. In addition, the breaking down of complex molecules by the action of enzymes is often employed in investigating the constitution of these substances.

The action of enzymes has been known for over 100 years. Kirchhoff in 1814 had discovered the catalytic action of the glutinous component of wheat meal, and later, in 1833, Payen and Persoz separated an active preparation of this enzyme from malt, the enzyme now known as amylase. While much work of a preliminary kind was carried out in the succeeding years, the results obtained were frequently inconsistent and confusing. This is not to be wondered at when we consider the excessive complexity of these bodies, the difficulties of purifying them and the extremely complicated reactions in which they play a part. It is again Willstätter, whose brilliant work on chlorophyll has just been described, who has been mainly responsible for the great advances which have been made in our knowledge of the enzymes during the past fifteen years. He began by improving the technique of the methods of preparation, introducing quantitative methods of control, and in this way was able to prepare specifically pure enzymes. This has led to a much more accurate knowledge of the specification of enzymes and has cleared up much of the confusion which existed previous to his work. He has investigated the colloidal characteristics of enzymes, the significance of the H-ion concentration of the medium and the action of enzymes as synthetic agents—to mention only a few of the outstanding results. In addition, a rational classification of the enzymes is now possible and much more detailed information about their specific action is available. While the chemical constitution of the enzymes has not yet been solved, there is no doubt that the results of Willstätter and his school have been most stimulating to those engaged in bio-chemical research and have had an important application to the many industries which make use of enzymes in manufacturing processes.

Vitamins.—A discovery which will always be associated with the name of the distinguished President of the Association this year (Sir Frederick Gowland Hopkins) is the importance in nutrition of the accessory food substances now known as vitamins. As far back as 1881, it was noticed that milk cannot be replaced by an artificial mixture of its chief constituents. In 1905 Pekelharing of the University of Utrecht made the striking claim that there is an unknown but essential substance in milk and other foods which is essential to nutrition. This work was overlooked, and it was not until the publication of Hopkins' work in 1912 that general interest was attracted to the subject. The progress since then in the study of these bodies is most striking. One of the most remarkable facts which have resulted from these investigations is the large number of substances of the vitamin type required for the proper nutrition of the higher animals, the number being stated to be at least nine. Ordinarily, five different vitamins are recognised, designated A, B, C, D and E. Vitamin B is now subdivided into no less than five substances, commonly referred to as the Vitamin B complex.

Vitamin A.—It is now fairly definitely established that Vitamin A is

formed by the liver from the pigment carotene ; this pigment occurs in carrots, green leaves, and various vegetables ; it is a hydrocarbon, $C_{40}H_{56}$, which is synthesised in plants by the action of light. Carotene has a deep colour, but Vitamin A is colourless. How carotene is converted into Vitamin A in the tissues is uncertain. The empirical formula $C_{20}H_{30}O$ (or $C_{20}H_{32}O$) has been suggested, and it appears probable that within the next few years the constitution of this vitamin will be known and then its preparation by synthetical methods will be a possibility.

Vitamin B.—Much work has already been carried out on the various members of the Vitamin B complex, but the position is still obscure and rather confusing. It is still uncertain how many active substances are present and there is still no general agreement as to their properties. B_1 and B_2 are the only two about which definite conclusions are at present available. B_1 has been obtained in the crystalline state and contains both nitrogen and sulphur. The provisional formula $C_{12}H_{17}ON_3S$ has been suggested. It is anticipated that the pure product will be available in the near future. While a considerable amount of work has been carried out as to the chemical nature of B_2, little definite information has yet been obtained.

Vitamin C.—The striking investigations of Szent-Gyorgyi and of Waugh and King have led to a great advance in our knowledge of this vitamin. What appears to be the essential substance in the vitamin was isolated and found to have the formula $C_6H_8O_6$; it was named hexuronic acid. The preparation of a larger quantity of the material from the juice of Hungarian red pepper by Szent-Gyorgyi has enabled the constitution of the acid to be worked out by Hirst, Cox and Reynolds at Birmingham. The substance is now named ascorbic acid, and its antiscorbutic properties are so marked that it may well prove to be Vitamin C itself.

Vitamin D is now available as a commercial preparation under the name ' Calciferol.' It is prepared by the irradiation of ergosterol with ultra-violet light ; its formula is $C_{27}H_{42}O$.

The discovery of vitamins has undoubtedly thrown much light on many of the difficult problems of nutrition and disease, and there can be no doubt that, as our knowledge of these substances increases, more and more use will be made of them in feeding. Already some notable advances have been made. The close connection between the yellow coloured pigment carotene and Vitamin A has just been referred to. Milk and butter produced in the summer months, when the cows are at pasture, have a yellow colour which is associated with the presence of carotene and of Vitamin A. On the other hand, butter produced from winter milk, when the cows are stall fed, is much whiter in colour and has a much lower content of carotene and Vitamin A. The popular view which associates the yellow colour of milk with ' richness ' is therefore not at fault, and incidentally the importance of prohibiting the colouring of butter and cheese should be mentioned. The problem was how to provide food with the necessary carotene or Vitamin A content during the winter months. Experiments on the artificial drying of grass carried out at the Agricultural Research Station at Jealotts Hill, Berkshire, have

shown that grass can be rapidly dried in a band drier at a temperature of 200° approximately, with scarcely any loss of digestibility or nutritive value and, what is more surprising, with only a small loss of the carotene content. It was also shown that the carotene content and the nitrogen content of pasture herbage were associated, grass of high nitrogen content being rich in carotene, so that by properly balanced manuring the carotene content of the pasture might be maintained at a higher level. A winter feeding experiment with cows was then arranged and the artificially dried grass was used to replace an equivalent amount of the ordinary food, with the result that the carotene and Vitamin A content of the butter was kept up. This effect was not produced by the addition of ordinary green silage. The importance to the public health of being able to produce in winter butter which, in regard to colour and Vitamin A content, is equal to the butter produced in summer from grass-fed cows, can hardly be over-estimated.

As regards vitamins generally, the most important problems are the differentiation of the different vitamins and the determination of the vitamin requirements of man and the higher animals. By the time this is done, it appears probable that there will be an abundant supply of pure vitamins to compensate for the deficiencies in the ordinary rations.

While talking of nutrition, the part played by the mineral matter of the food must also be mentioned and the necessity for maintaining a correct ratio between the basic and acidic constituents. Much important work has been carried out in this country in recent years by the Rowett Institute and the Animal Nutrition Research Institute at Cambridge on the mineral content of pastures. In his Presidential Address at Bristol in 1930 Prof. Du Toit described the far-reaching results of Theiler's work in South Africa on phosphorus deficiency, and referred also to Aston's work on iron deficiency in New Zealand.

Agricultural Development.

Sufficient has been said of the scientific advances in recent years to indicate the great importance of their application, when possible, to agricultural industry. At one time it was only too apparent that there existed a long lag between scientific discovery and its application in agricultural research, but this has diminished considerably in recent years; indeed, it may now be said that any new line of work is almost at once turned to account in agricultural investigation.

This agricultural work is undertaken mainly at the new agricultural research institutes, although a considerable amount of work is still carried out at the universities and the agricultural colleges.

The development of these research institutes has been one of the most marked advances connected with agricultural science which have taken place in recent years.

In Scotland alone, for example, institutes have been established within the last few years for research in animal nutrition, in animal diseases, in animal genetics, in plant breeding, in dairying and in soil science, and the progress in England has been equally great.

How are the results of these investigations brought before the farmer

and what is his response to them ? How far are they being incorporated into modern agricultural practice ?

It is one of the functions of the agricultural colleges to be the connecting link between the research institutes and the farmer. Advisory services in connection with the colleges now cover the whole country, so that farmers desiring advice have it provided at their own doors and without cost. Mention must also be made of the services of the Ministry of Agriculture and Fisheries, the Department of Agriculture for Scotland and the Ministry of Agriculture for Northern Ireland, whose various publications, journals, bulletins, etc., contain much valuable information.

As to the reaction of the farmer, one is bound to admit that, owing to the inherent disinclination of the older farmers to listen to new ideas, the response is not what we should desire. At the same time, the more intelligent and progressive farmers are fully aware of the value of the advisory work of the colleges and make use of them regularly. The whole attitude of the farmer to the colleges is vastly different from what it was twenty-five or thirty years ago, and the amount of advisory work is increasing year by year.

This much must be admitted, however, that there is still room for improvements in agricultural methods and that much of the farming still requires to be raised to the level of the best practice.

We may state, therefore, with confidence that the difficulties of present-day agriculture are not due to the lack of scientific advice available to the farmer ; indeed, it is even sometimes alleged that the present-day troubles of agriculture are due to scientific research and to an abnormal increase in production ; even the Minister of Agriculture remarked semi-humorously the other day : ' Improvements in technique are the great curse of the modern world. Some infernal scientist comes along and shows us how two blades of grass can be made to grow where one was before. Instead of that being the highest praise, it is one of the most damning accusations you can make against any man or any country just now.' An amusing piece of invective, but no help to us in our difficulties.

In a paper contributed to this Section last year at York, Mr. E. M. H. Lloyd, the Assistant Secretary of the Empire Marketing Board, quoted figures to show that the world production of food stuffs and raw materials, though it increased rapidly after the set-back due to the war, had not reached, in 1929, the continuation of the pre-war trend. The statistics suggest that world agricultural production is, in fact, less now than it would have been but for the war. ' The agricultural crisis is due to the fall in prices ; and this fall of prices is due more to diminution of effective demand through a contraction of consumers' money incomes than to any exceptional increase of supply.'

It is certain, therefore, that the advances in the application of science to agriculture are not the causes of the prevailing agricultural depression throughout the world, but that these are to be sought for in the absence of satisfactory schemes of collective planning, marketing, stability in the value of money and the maintenance of better equilibrium between prices, wages and debts, to quote again from Mr. Lloyd.

Whatever opinion may be held as to over- or under-production of agri-

cultural produce in the world as a whole, this much at any rate is clear: that an increased production of home-grown food is of paramount importance to our own country.

There are two main reasons why this is so urgent. We have to remember that in the industrial changes which have taken place since the war many of our industries have either disappeared or have been so reduced in amount that there has been a serious displacement of labour. So far as one can see, there is no prospect of these industries recovering their former size in this country, and, while new industries may be introduced, there is a grave fear that the displacement of many workers from their previous occupations is permanent. No better way of using this displaced labour can be imagined than to employ it on the land to increase our home agricultural production. It is unnecessary to point out or minimise the obstacles to so profound a change—the disinclination of an urban population to move to the country, the problems of housing and wages, and the necessity of obtaining a remunerative price for the food produced are only some of the more obvious difficulties involved.

The second reason is equally important, and that is to supply the consumer with as large a proportion as possible of fresh food which has not been subjected to chilling or freezing or to any of the chemical manipulations or treatment which are much too common nowadays. The deleterious effects of some of these processes on the general quality of food is now well appreciated, and it is certain that, no matter how carefully these methods are carried out and controlled, the resulting product is not as good as the fresh material. The aim of the home producer should be, therefore, to produce the type of food in largest quantity where this quality of freshness is of the highest importance—e.g. meat, milk, butter, eggs, poultry and market-garden produce and fruit. In this way he can best meet the menace of overseas competition. At the same time much work will require to be done to educate the consumer to appreciate the superior value of fresh home-grown food as against that which has been chilled or preserved. It is quite certain that the consumer will not purchase home-grown produce for sentimental reasons: he will have to be convinced that the quality is better and that he is getting equally good value for his money. It will be necessary in this connection for the home producer to study the public taste a little more carefully perhaps than he has done in the past.

The modern farmer must now choose between two courses. He may either adhere to traditional systems under which his products have to meet those of overseas competitors who possess dominant advantages in the production of most of their crops, or, on the other hand, he may alter his system to meet the new conditions and produce those commodities which will command an unassailable position in the home market.

This alteration in the system of farming will mean many important changes; more concentrated foods must be grown, e.g. beans and peas, and less concentrated foods imported. In this connection the highly nutritive quality of young grass and the methods for its utilisation should receive more attention; the growing of hay on a quality basis and the adequate use of silage should also be mentioned.

Another problem to which sufficient attention is not being paid at present is the use of the poorer quality of land, such, for example, as we find in Scotland at elevations of 600 feet and over. Much of this, under proper methods of management, could produce a larger number of store cattle, milk and milk products, and poultry than it does at present. In more favourable times the possibility even of further land reclamation should not be overlooked. It may seem futile at a time when there is such difficulty in getting any adequate return from our best land to suggest that further land should be reclaimed ; the present conditions, however, will not, we hope, be permanent, and we have to consider what may be possible in more normal times. The spectacle of large areas of land suitable for reclamation and close to our great industrial centres reflects little credit on the agricultural policy of the past generation or two. In many of these areas there are abundant supplies of labour near at hand, and the difficulties of housing and transport would be reduced to a minimum. It is not suggested that at the present such reclamation would be economic, but as a means of using unemployed labour it would at least have the merit of leaving something tangible as the result. In an article contributed to *The Times* last November, Sir Daniel Hall gives an interesting account of the enormous reclamation and land drainage work which has been carried out in Italy during the past ten years, and points out that the agriculturally minded man must regard it as the biggest bit of constructive work since the war ended. In conclusion he says : ‘ A great work. But what of the cost ? As yet, it is impossible to judge of the finance, for who shall say what land is worth or is going to be worth ? But the Italian State is said to have expended £31,000,000 gold in the last ten years on " Bonifica," against which it is claimed that over a million acres have been or are being reclaimed. The severely economic English view would be that, since land is going out of cultivation, it is waste of money to make more. But in Italy men do still live by the land ; the money has been spent in Italy and almost wholly on labour, and there is something real and lasting to show for the expenditure. It is a return to the high Roman way, to the courage that drove the first roads and built the bridges through Barbarian Europe.’

The importance of agriculture, not merely as a means of producing additional home-grown food but as an industry of fundamental social value, is now being realised by all sections of the community.

With the good offices of statesmen, scientists, economists and others interested, and with the goodwill of the people at large, it is not too much to hope that the British farmer will choose wisely, and that the character and energy which have distinguished him for generations will enable him to secure once more for our British agriculture that prosperity which is vital to the welfare of our nation.

REPORTS ON THE STATE OF SCIENCE,

Etc.

SEISMOLOGICAL INVESTIGATIONS.

Thirty-eighth Report of Committee (Dr. F. J. W. Whipple, *Chairman*; Mr. J. J. Shaw, C.B.E., *Secretary*; Prof. P. G. H. Boswell, O.B.E., F.R.S., Dr. C. Vernon Boys, F.R.S., Sir F. W. Dyson, K.B.E., F.R.S., Dr. Wilfred Hall, Dr. H. Jeffreys, F.R.S., Sir H. Lamb, F.R.S., Mr. A. W. Lee, Prof. H. M. Macdonald, F.R.S., Prof. E. A. Milne, M.B.E., F.R.S., Mr. R. D. Oldham, F.R.S., Prof. H. H. Plaskett, Prof. H. C. Plummer, F.R.S., Prof. A. O. Rankine, O.B.E., Rev. J. P. Rowland, S.J., Prof. R. A. Sampson, F.R.S., Mr. F. J. Scrase, Dr. H. Shaw, Sir Frank E. Smith, K.C.B., C.B.E., Sec.R.S., Dr. R. Stoneley, Mr. E. Tillotson, Sir G. T. Walker, C.S.I., F.R.S.).

Dr. J. E. Crombie.—In August 1932 the Committee lost one of its most valued members by the death of Dr. J. E. Crombie, who had served since 1915. He was a practical seismologist and maintained in turn in his beautiful home near Aberdeen seismographs of several patterns, the last one being a Milne-Shaw. In 1919 when a home had to be found for the seismological equipment and library from Milne's station at Shide in the Isle of Wight, Dr. Crombie provided funds, which were, after some delay, devoted to paying part of the cost of a well-schemed extension of the University Observatory at Oxford. It was his generous help that enabled Prof. Turner to continue the international seismological work through the years of financial stringency. Dr. Crombie was a man of many interests, and served well his University and the City of Aberdeen. His memory is held in honour by his colleagues on the Seismological Committee.

By his will Dr. Crombie provided that on the death of his wife his trustees should allocate the sum of £1,000 free of Government duties to the Seismological Committee of the British Association 'to be applied towards assisting in the investigation of seismological research.'

Dr. Crombie's seismographs were bequeathed to the University of Aberdeen. The Milne-Shaw seismograph has been set up for trial in a cellar at King's College, Aberdeen. An Agamennone seismograph has been presented to the Science Museum, South Kensington, which already had a Mainka seismograph given by Dr. Crombie. His other Mainka seismograph remains at Aberdeen.

Finance.—The Accounts for the year ending June 30, 1933, differ in several respects from those for the preceding year. The new scale of subscriptions adopted by the International Union for Geodesy and Geophysics in 1930 came into force in 1932 and in spite of prognostications, on which the statement in the last report 'no increase in the subvention from the International Seismological Association towards the cost of the International Seismological Summary is to be anticipated' was based, there has been an increase from £259 to £404. In view of this increase, the Committee was

able to withdraw the application to the Council of the British Association for a special grant for the year.

On the other side of the General Account there is a large saving in printing, but a new item appears, the Committee having accepted for this year the responsibility, formerly borne by Dr. Crombie, for part of the salary of the scientific assistant at the University Observatory, Oxford.

The income of the Gray-Milne Trust Fund has fallen (temporarily it is hoped owing to the lapse of the dividend due from the Canadian Pacific Railway. There has been no considerable call on the Fund during the year. It is anticipated, however, that the charges for printing the memoir by Messrs. Jeffreys and Bullen referred to below will come out of the Fund.

It is hoped that at the meeting at Lisbon in September 1933 of the International Seismological Association such a grant will be given to the University Observatory, Oxford, as will allow the work on the International Seismological Summary to be continued there. The Committee wishes to assist the Observatory by devoting to this purpose the £100 payable from the Caird Fund. The Committee is not asking for an additional grant this year.

ACCOUNTS, JULY 1932–JUNE 1933.

General Account.

	£	*s.*	*d.*		£	*s.*	*d.*
Brought forward .	192	3	8	I.S.S.—Printing .	254	15	0
B.A. Caird Fund .	100	0	0	Printing and Stationery	4	9	1
U.G.G.I., for I.S.A. .	404	11	3	Postage	12	2	5½
Sale of I.S.S. . .	0	13	7	Computing . .	87	11	5
Bank Interest . .	0	7	0	Scientific Asst. (Salary, Part) . .	150	0	0
				Translation . .	0	10	0
					509	7	11½
				Operation of Seismographs . . .	8	16	7
				Committee expenses .	0	10	0
					518	14	6½
				Balance carried forward	179	0	11½
	£697	15	6		£697	15	6

Gray-Milne Trust Account.

	£	*s.*	*d.*		£	*s.*	*d.*
Brought forward .	342	19	3	Miss Bellamy (Honorarium) . . .	30	0	0
Trust Income . .	66	14	10	Milne Library . .	4	14	0
Bank Interest . .	1	13	8	Fire Insurance . .	0	15	0
				Press Cuttings . .	1	1	0
					36	10	0
				Balance . . .	374	17	9
	£411	7	9		£411	7	9

The International Seismological Summary.—During the latter half of 1932 there were two issues of the Summary. These completed the volume for the earthquakes of 1928. The issues containing the Summary for the first two quarters of 1929 have been printed. Prof. Plaskett reports that the MS. for the rest of that year is nearly ready for the printer. As far as the records for 1930 have been received, they have been copied on to cards in readiness for analysis. It is proposed to take into use at once such new tables as may be adopted at the meeting of the International Seismological Association at Lisbon.

Seismographs.—The five seismographs belonging to the British Association have remained on loan to the Seismological Stations at Oxford (2), Edinburgh, Perth (W. Australia) and Cape Town.

Interesting memorials of the earliest seismological station in England have been obtained recently by the Science Museum, South Kensington. Early in 1932 Miss Morey of Newport, Isle of Wight, presented to the Museum the original lamp-post on which Milne erected his first seismograph at Shide. The drum and recording mechanism of this seismograph, which were in the possession of Mr. W. H. Bullock, have been purchased and an effort is to be made to reconstruct the apparatus as accurately as possible.

A good many parts of old instruments from Milne's workshop are now at the University Observatory, Oxford, but it appears that there is nothing of definite historical interest, and with the approval of this Committee Prof. Plaskett will dispose of the material at his discretion. Some of the parts found in this collection have been lent to the Rev. H. Pain of Turville Vicarage, Henley-on-Thames, who has constructed a seismograph and obtained good results.

During the year the Milne-Shaw seismographs supplied by Mr. Shaw to the Department of Geology, Liverpool University, and to the Department of Geology, University of Vermont, have been brought into operation.

British Earthquakes.—A valuable paper dealing with the macroseismic evidence of four recent Scottish earthquakes has been published by Dr. G. W. Tyrrell in the *Transactions* of the Geological Society of Glasgow, Vol. xix, Part I, 1931–32. The shocks examined are :

(1) The Oban earthquake of 1925, December, $23^d\ 12^h$.
(2) The North Sea earthquake of 1927, January, $24^d\ 5^h$.
(3) The Collentraive earthquake of 1927, January, $27^d\ 9^h$.
(4) The Lochgilphead earthquake of 1927, January, $27^d\ 16^h$.

On January 14, 1933, at about 8^h30^m an earthquake was felt over a large area in the North of England ; and a slight after-shock, felt at 16h. 3m. on the 17th, was recorded at Stonyhurst. A report on this earthquake has been prepared by the Rev. J. P. Rowland. An earthquake which was felt in Jersey on April 12 was recorded by seismographs in England.

Small disturbances not recorded by seismographs were reported by newspapers as occurring on the following dates : 1932, December 31, Devon ; 1933, April 23, Canterbury. A weak tremor, reported as being felt at Great Harwood, Lancs., on 1933, July 7, was reported at Stonyhurst at 12h. 1m.

The Revision of Seismological Tables.—The following note has been contributed by Dr. H. Jeffreys and Mr. K. E. Bullen :

The observations recorded in the I.S.S. from 1923 to 1929 are being used to construct revised tables for the principal waves recorded in large earthquakes. The method used is equivalent to a least-square solution by successive approximation. The numbers of earthquakes used in the respective regions are: Europe, with the Mediterranean and Central

Asia, 10 ; North and Central America, with the North Atlantic, 19 ; South America, 4 ; Japan, 15 ; Pacific and Indian Oceans, 9 ; total, 57. These have been selected as specially well observed and capable of having the epicentres well determined from the data.

The solution for P proved to be straightforward. The times already found by H. J. and published by the Committee were right within a second up to about 19° ; but there is a sharp bend in the curve at this distance, the maximum correction needed being − 5.7s. at 30°. Beyond that distance smaller corrections are needed, reaching + 1s. about 60°. At greater distances still the corrections are again negative, reaching − 3s. at 105°.

In the case of S there was much difficulty owing to misidentifications. It seems that the H. J. tables are nearly right to 15°, but need a slight increase to 19°, and that there is at this distance a discontinuity similar to that found for P ; a correction of − 8.7s. is needed at 30°. The correction vanishes about 60° and is about +4s. beyond 80°.

The waves through the core[1] have also been discussed and times have been found for PKP(= P′ = P_cP_cP), SKS(= S_cP_cS) and SKKS(= $S_cP_cP_cS$). The forms of the curves differ very little from those given by Gutenberg, but additive constant corrections are needed to adapt them to the same focal depth. Times for the diffracted P at distances up to 143° have been obtained.

The outstanding problems relate to the determination of focal depth and of the depths at which PP, PS and SS are reflected. So long as the focus is within the upper layers the effect of focal depth is simply to make S arrive early by about the same amount at all distances, the forms of the P and S curves remaining unaltered. This additive constant can be determined and allowed for. But it remains doubtful to what focal depth the standard S curve corresponds ; though several methods have been tried none seems satisfactory. The additive constant varies between different earthquakes by as much as 18s. This is inconsistent with the supposition that P movement is always generated by the original shock ; in that case the variation could only be about 5s. There seems to be no doubt that in some earthquakes there is primitive P movement and in others none. All the curves have been made to correspond to the same focal depth, but there remains some doubt as to what that depth is. Some earthquakes not recorded as having deep foci in the I.S.S. have proved to have foci 50 to 100km. below the top of the lower layer.

PP, PS and SS are frequently recorded, but the residuals are irregular and it is still uncertain whether any definite conclusions can be drawn from them.

The bends in the P and S curves at 19° may be the result of either a rapid continuous increase of velocity or a discontinuity at a depth of about 400km., the velocities rising by about 10 per cent. when it is crossed. On the former alternative points of large amplitude would occur, which have been sought by Miss Lehmann but not found. A discontinuity on the other hand would give reflexions, which again have not been found, but their amplitudes would in any case be small. The most likely one to be observable may be one of PP type reflected on the inside of the discontinuity, just as SKKS is the best observed reflexion on the surface of the central core.

Other waves recorded with fair frequency are PKS, P'_2 and SKSP. An attempt will be made to construct empirical tables for these also.

Valuable supplementary information has been received in correspondence with other seismologists, especially Miss I. Lehmann, Miss E. F. Bellamy

[1] The letter K is used for a compressional wave through the core (*Kernwelle*). The notation is taken from Bulletins issued from Georgetown.

and Messrs. Gutenberg, Scrase, Byerly and Hodgson. This will be acknowledged more fully later.

High Focus Earthquakes.—That earthquakes with deep foci occur is well established, but the significance of the observations which led Turner to attribute high foci to certain earthquakes is not yet known. Mr. E. Tillotson has chosen for investigation an earthquake of this type, 'The African Rift Valley Earthquake of 1928, Jan. 6.' Mr. Tillotson has examined about 100 original records of this earthquake. There is no doubt as to the location of the epicentre, which is in the Subukia Valley, Kenya Colony. The anomalies in the observations are still under consideration.

Microseisms.—The discussion, by Mr. A. W. Lee, of the microseisms recorded in all parts of the world during January 1930 has been completed and will be published shortly. Data are available for 57 observatories. The most disturbed of them are Reykjavik and Honolulu.

In Europe microseismic storms do not occur in the absence of barometric depressions over the eastern part of the Atlantic, but some deep depressions are not accompanied by large microseisms. No evidence for a direct connection between microseismic disturbance and the sea-disturbance in particular regions has been found.

Periodicity of Earthquakes.—Two notable papers by Dr. C. Davison (a former member of the Committee) on periodicity in earthquakes have appeared recently in the *Philosophical Magazine* (Ser. 7, Vol. 15 (1933)). In the first paper the eleven-year period is discussed on the basis of statistics covering the whole globe and the last two centuries. It is found that in all parts of the world earthquakes are more frequent in the years of many sunspots. In the second paper a 19-year period is investigated. In this case the maximum frequencies of the northern hemisphere tally with the minimum frequencies of the southern hemisphere. The period seems to be identical with the nutation period of the earth and it is therefore demonstrated that the strains associated with the movements of the earth's axis are factors in determining when earthquakes shall occur.

Reappointment.—The Committee asks for reappointment and for the confirmation of a grant of £100 from the Caird Fund.

MATHEMATICAL TABLES.

Report of Committee on Calculation of Mathematical Tables (Prof. E. H. NEVILLE, *Chairman*; Prof. A. LODGE, *Vice-Chairman*; Dr. L. J. COMRIE, *Secretary*; Dr. J. R. AIREY, Prof. R. A. FISHER, F.R.S., Dr. J. HENDERSON, Dr. E. L. INCE, Dr. J. O. IRWIN, Dr. E. S. PEARSON, Mr. F. ROBBINS, Mr. D. H. SADLER, Dr. A. J. THOMPSON, Dr. J. F. TOCHER, and Dr. J. WISHART).

General activity.—Six meetings of the Committee have been held, in London.

The grant of £50 has been expended as follows:

	£	s.	d.
Calculations connected with the Bessel functions $\mathcal{J}_{\frac{1}{3}}(x), \mathcal{J}_{-\frac{1}{3}}(x), \mathcal{J}_{\frac{2}{3}}(x), \mathcal{J}_{-\frac{2}{3}}(x)$	27	10	0
Calculations connected with the confluent hypergeometric function	10	0	0
Calculations connected with the Bessel functions $Y_0(x)$ and $Y_1(x)$ for $x = 6{\cdot}0(0{\cdot}1)16{\cdot}0$	7	10	0
Secretarial expenses	5	0	0

Cunningham Bequest.—(*a*) The work on the table of reduced ideals and primitive units in real quadratic fields has been continued by Dr. E. L. Ince. It is hoped that the manuscript will be ready for the printer by the end of this year.

(*b*) The printing by a photographic process of Prof. L. E. Dickson's tables of the minimum decompositions of the numbers 1–300,000 into fifth powers has been put in hand. This will constitute the Committee's Volume III.

(*c*) The Council has authorised the preparation and publication of a volume containing all the prime factors of all numbers up to 100,000.

The calculations are being done voluntarily, in duplicate, one copy by Mrs. E. Gifford, and the other by Miss E. J. Ternouth, of Reading University, and Prof. A. Lodge.

(*d*) The purchase, for table-making, of a National Accounting machine (formerly called the Ellis) has been authorised, and the machine is now on order. It contains an eleven-column keyboard, printing mechanism, and six adding mechanisms.

Bessel functions.—The sub-committee formed to draw up a report on the tables of Bessel functions which have appeared in the Reports of the Committee, with a view to the possibility of their publication in one volume, has now completed the examination of these tables. Interim reports were made during the session, and action was taken for the preparation of the Y functions. The full report and recommendations of the sub-committee will be considered during the next session.

The Committee has calculated, at the request of Dr. R. Stoneley, 7-figure tables of the functions $J_{\frac{1}{4}}(x)$, $J_{-\frac{1}{4}}(x)$, $J_{\frac{3}{4}}(x)$, $J_{-\frac{3}{4}}(x)$, for the range $x = 0{\cdot}00(0{\cdot}01)0{\cdot}50(0{\cdot}02)2{\cdot}50(0{\cdot}05)5{\cdot}0(0{\cdot}1)20{\cdot}0$.

The preparation of printer's copy of $J_0(x)$ and $J_1(x)$ to 10 decimals for $x = 0{\cdot}000(0{\cdot}001)16{\cdot}00(0{\cdot}01)25{\cdot}00$ has been completed, as has also copy of 8-figure values of $I_0(x)$ and $I_1(x)$ for $x = 0{\cdot}000(0{\cdot}001)5{\cdot}000$.

The preparation of an 8-figure table of $Y_0(x)$ and $Y_1(x)$ for $x = 0{\cdot}00(0{\cdot}01)16{\cdot}00$ has been begun, and will be carried to completion next year.

Airy integral.—The Committee has received a request from Dr. H. Jeffreys for the tabulation of the Airy integral and its first derivative. It is hoped that this may be done next year.

Confluent hypergeometric functions.—The Committee has received a request from Dr. R. Stoneley for certain calculations in connection with these functions. The work is being put in hand by Dr. A. J. Thompson.

Publication.—The Committee has expressed to the Council its desire for the publication of the following material:

(1) The Legendre functions described in the last report;
(2) The Bessel functions of orders $\pm\frac{1}{4}$ and $\pm\frac{3}{4}$ described in this report;
(3) The Bessel functions $J_0(x)$, $J_1(x)$, $I_0(x)$ and $I_1(x)$ described in this report.

Reappointment.—The Committee desires to be reappointed, with the addition of Dr. J. C. P. Miller, and with a grant for general purposes of £100.

QUANTITATIVE ESTIMATES OF SENSORY EVENTS.

Interim Report of Committee appointed to consider and report upon the possibility of Quantitative Estimates of Sensory Events (Dr. A. Ferguson, *Chairman*; Dr. C. S. Myers, C.B.E., F.R.S., *Vice-Chairman*; Mr. R. J. Bartlett, *Secretary*; Dr. H. Banister, Prof. F. C. Bartlett, F R.S., Dr. Wm. Brown, Dr. N. R. Campbell, Dr. S. Dawson, Prof. J. Drever, Mr. J. Guild, Dr. R. A. Houstoun, Dr. J. O. Irwin, Dr. G. W. C. Kaye, Dr. S. J. F. Philpott, Dr. L. F. Richardson, F.R.S., Dr. J. H. Shaxby, Mr. T. Smith, F.R.S., Dr. R. H. Thouless, Dr. W. S. Tucker).

The Committee met on four occasions; memoranda prepared by members have been circulated.

The memoranda which have been circulated have dealt critically with (*a*) the possibility of quantitative estimates of sensory events, (*b*) the meaning of the term *measurement* in its application to the estimation of sensory magnitudes, and (*c*) the validity of the modes of presentation and interpretation of the Weber-Fechner law.

The matters so raised and discussed have resulted in the resolving of many doubtful points and in raising clear-cut issues of fundamental importance, but it is evident that further discussion and research are necessary before a satisfactory synthesis of opinion can be effected.

The Committee is agreed that (*a*) a critical *résumé* of past work on the Weber-Fechner law, paying special attention to experimental conditions and introspective reports, would be of great value; and that (*b*) further experimental work should be undertaken on the measurement of *just noticeable differences*, *equal-appearing intervals*, and *ratio estimates* in the various sensory fields, full use being made of modern physical instruments.

In furtherance of the above, at the suggestion of the Committee, work has been commenced at Cambridge, at Cardiff and at Edinburgh, and it is hoped that other psychological laboratories will be able to give assistance later.

The main work of the Committee is necessarily carried out by the interchange of memoranda between its members, and the Committee desires to record its indebtedness to the Council of the British Psychological Society for their hospitality and for the assistance which they have given in the duplication of the memoranda involved.

The Committee asks to be reappointed, without grant.

TERTIARY AND CRETACEOUS ROCKS.

Report of Committee appointed to investigate Critical Sections in the Tertiary and Cretaceous Rocks of the London Area and to tabulate and preserve records of new excavations in that area (Prof. W. T. Gordon, *Chairman*; Dr. S. W. Wooldridge, *Secretary*; Mr. H. C. Berdinner, Prof. P. G. H. Boswell, O.B.E., F.R.S., Miss M. C. Crosfield, Mr. F. Gosling, Prof. H. L. Hawkins, Prof. G. Hickling).

The grant allotted to the Committee for 1932–33 was expended in investigating the structure of a critical area south of the Lower Greensand

escarpment near Nutfield, Surrey. Here and eastwards at Tilburstow Hill, Godstone, a number of outliers occur south of the main scarp. The beds in several cases are highly inclined and much disturbed, and at first sight a strong suggestion is conveyed of a major fault parallel to, but to the south of, the main escarpment. Such a fault would lie in a known zone of tectonic instability, and would form an important element in Wealden structure. An alternative hypothesis attributed the outlying disturbed masses to large scale slip-faulting of the type seen on many British sea-coasts, as well as along the banks of the Panama Canal. A large number of borings were made under the supervision of Mr. F. Gosling, B.Sc., F.G.S., and the evidence from these has been brought together in maps and sections, which it is hoped will shortly be published. The evidence so far obtained is definitely opposed to the hypothesis of regional faulting, but enables the detailed reconstruction of a structural arrangement consistent with bodily slipping of portions of the former scarp-face. An important contributory factor in the process here, and probably elsewhere, is the flattening, or reversal of the general northerly dip, in the vicinity of the present escarpment.

SEX PHYSIOLOGY.

Final Report of Committee on the Influence of the Sex Physiology of the Parents on the Sex-ratio of the Offspring (Prof. J. H. Orton, *Chairman*; Mrs. Ruth C. Bisbee, *Secretary*; Prof. A. M. Carr-Saunders, Miss E. C. Herdman).

The Effect of Altered Sex Physiology of the Parent on the Sex Ratio of the Offspring in Guinea-pigs.

Some years ago a series of experiments was carried out and yielded extremely interesting results. Some male guinea-pigs each had one testis removed when only a few weeks old. When they became adult they were used for breeding, and gave offspring in the proportion of 2 ♀♀ : 1 ♂. As there were more than 300 young, it seemed fairly certain that the proportions were not due to chance.

An attempt has been made during the past three years to repeat these experiments on a small scale, but the animals have bred so slowly that the number of offspring is still too small to give a conclusive result. As they are breeding so slowly it has been decided not to continue the experiments during the coming year, but to wait until the animals can be kept under more normal conditions. It is not proposed, therefore, to ask for any further grant at the present time.

A grant of £5 was received last year and was used for the maintenance of the stock.

Mrs. Bisbee wishes to express her gratitude to the Committee for the financial help which she has received, and to assure them that the work will be continued as soon as possible.

ZOOLOGICAL BIBLIOGRAPHY.

Zoological Bibliography and Publication (Prof. E. B. Poulton, F.R.S., *Chairman*; Dr. F. A. Bather, F.R.S., *Secretary*; Mr. E. Heron-Allen, F.R.S.; Dr. W. T. Calman, F.R.S., Sir P. Chalmers Mitchell, C.B.E., F.R.S.; Mr. W. L. Sclater).

During the past year the Secretary has been consulted on various questions of publication and has offered advice in the terms of previous reports by the Committee.

A difficult question has been raised by the Entomological Society of the South of England regarding the publication of papers reproduced by duplicator or other methods than type printing. The Society suggests that a minimum limit of 500 copies should be fixed and that the papers should in all other respects conform to the requirements of the International Rules of Zoological Nomenclature (which are essentially the same as the conditions laid down by your Committee). We do not think that any distinction can be drawn between the various processes of multiplying copies, provided that the results are reasonably permanent. The size of the edition must be governed by ordinary economic forces and by the probable number of people interested in the particular subject. It is important that the publication should be advertised; an edition of 50,000 would be of little use if not made known.

Attention is again drawn to the undesirability of mentioning the systematic name of an animal in the title of a paper without any indication of the class to which it belongs. Editors of publications in applied, economic, and ecologic zoology would help their colleagues by insisting on closer adherence to the accepted rules and methods of nomenclature.

It may assist editors and authors if we mention that the International Rules of Zoological Nomenclature, as well as other information of use in preparing papers, have recently been printed in the following:

Krejci-Graf, Karl. 'Scientific Nomenclature and the Preparation of Papers.' *Geol. Surv. Kwangtung and Kwangsi.* Special Publication. XII. Canton. December 1, 1932.

Pearson, Joseph. 'Ceylon Journal of Science. Instructions and Rules to be observed by Authors and Editors.' March 1933. Private circulation only.

The Secretary has protested in *Nature* (vol. cxxxii, p. 102, July 15, 1933) against the waste of time caused by the omission of page numbers from the opening pages of chapters, articles, and so forth.

The Committee seeks re-appointment with the same constitution as last year, and without a grant.

HUMAN GEOGRAPHY OF TROPICAL AFRICA.

Report of Committee appointed to inquire into the present state of Knowledge of the Human Geography of Tropical Africa and to make recommendations for furtherance and development (Prof. P. M. Roxby, *Chairman*; Prof. A. G. Ogilvie, O.B.E., *Secretary*; Prof. C. B. Fawcett, Prof. H. J. Fleure, Mr. E. B. Haddon, Mr. R. H. Kinvig, Mr. J. McFarlane, Col. M. N. MacLeod, D.S.O., M.C., Prof. J. L. Myres, F.B.A., Mr. R. U. Sayce, Rev. E. W. Smith, Brig. H. S. L. Winterbotham, C.M.G., D.S.O.).

Past Activities of the Committee.

The Committee, which was first appointed after the Oxford Meeting of the Association in 1926, was occupied during the first period of its work in bringing its proposed activities to the notice of a wide circle of people in Africa who are in a position to supply data. This was most effectively done by the issue of a pamphlet of 46 pages, first printed in 1930 and reprinted in 1931, containing: (1) An introduction setting forth the nature of the gap in our knowledge of the material life of African natives, in so far as it relates to the use of land and is directly affected by local environment; (2) a list of subjects upon which information is specially required; and (3) reprints of two essays of the kind which the Committee desired to receive from residents throughout Africa, these reprints to be regarded as models.[1]

This pamphlet was sent: (1) in bulk to the Governments of the various British Colonies and Mandates in Tropical Africa, and was distributed by them to their local officers, and (2) to a number of selected missionaries and other residents. The response from members of the latter group has been slight, but there is every indication that the interest of Government Officers in various parts of Africa has been aroused. The Committee has already been able to procure publication of an essay by Mr. L. H. L. Foster on the Mlanje District of Nyasaland (*Geography*, 1932), and is now seeking publication for two reports from Tanganyika Territory, by Mr. G. D. Popplewell and by Messrs. E. A. Leakey and N. V. Rounce respectively. Other documents have been received which, though not suitable for separate publication, yet furnish much useful information. Among these are a paper by Mr. R. C. Northcote on the Rungwe District of Tanganyika Territory, and reports on specific points by officers of the Agricultural Department of Sierra Leone. To all of these gentlemen the Committee gratefully acknowledges its debt.

The Committee has further obtained co-operation in several of the University Geography Departments in this country, especially with the view of constructing population maps of the African Colonies.

Northern Rhodesia.

While the Governments of all the Colonies have helped the Committee by distributing the pamphlet, the Government of Northern Rhodesia

[1] Arrangements have now been made by which copies of the pamphlet may be obtained, price 7d., post free, from the Clerk, Geographical Association, Municipal High School of Commerce, Princess Street, Manchester.

invited all the District Officers of the territory to submit reports. Twenty-eight of these District reports have now been received by the Committee, while only five remain to be sent in. Thus, by the acquisition of what it is hoped will soon be material for a complete review of the human geography of a large African territory, the Committee is enabled to enter upon the second stage of its work, that of examining, collating and making available to a wider circle the information so generously compiled by the responsible officers on the ground.

The Committee gratefully acknowledges the courtesy extended to it by the Government of Northern Rhodesia, and hopes to make the fullest use of the results thus acquired as soon as possible, when it will make the proper acknowledgment to the individual contributors.

Further Outlook.

The Committee having received certain reports, as above mentioned, from other East African territories, hopes that the latter Colonies will in the near future yield more comprehensive material. It seems likely that this result may be hastened by the present visit to East Africa of Mr. S. J. K. Baker, a former member of the Committee.

It is of course recognised that while the data now accumulating have their chief value as contributions to knowledge of specific geographical relationships, they will also possess considerable value to anthropological and ethnological studies. The Committee therefore intends to establish and maintain close touch with bodies which for any reason may be interested in the material accumulated, such as the Royal Anthropological Institute, the Royal Institute of International Affairs, and the International Institute of African Languages and Cultures.

In short, it will be seen that the real work of the Committee lies before it.

Reappointment and Expenses.

The Committee therefore asks to be reappointed, with the addition of the names of Mr. S. J. K. Baker, Dr. A. Geddes, and Mr. R. A. Pelham. It asks for a grant of £5 to cover secretarial expenses in 1933–34, and it intimates that any profits accruing from sale of the pamphlet will be handed to the General Treasurer of the Association.

GEOGRAPHY IN DOMINION UNIVERSITIES.

Report of Committee appointed to ascertain the place which Geography occupies in the curricula of the universities in the various Dominions of the Empire (Prof. C. B. Fawcett, *Chairman*; Dr. L. Dudley Stamp, *Secretary*; Dr. L. J. Burpee; Prof. F. Debenham; Dr. C. A. E. Fenner; Prof. Griffith Taylor; Prof. J. H. Wellington).

1. Activities of the Committee.

Having collected preliminary suggestions from the members of the Committee then in England, the Chairman and Secretary met and drew up a draft of a letter and questionnaire to be circulated to all universities concerned. These drafts were circulated to the members of the Committee

for suggestions and approval. It was agreed to co-opt Dr. Benson to help in New Zealand. Copies of the letter and circular as finally approved by members of the Committee were then duplicated (Documents A and B attached) and distributed as follows :—

(*a*) in bulk to Dr. L. J. Burpee for distribution to Canadian universities and the collection of replies.
(*b*) in bulk to Dr. C. Fenner for Australia.
(*c*) in bulk to Prof. J. H. Wellington for South Africa.
(*d*) in bulk to Dr. W. N. Benson for New Zealand.
(*e*) in bulk to Prof. Griffith Taylor for the collection of comparable details of the leading universities of the United States.
(*f*) individually by the Secretary to the universities of India, Singapore, and Hong Kong.
(*g*) individually by the Secretary to the universities and university colleges of the British Isles for the collection of comparable details.

An Interim report was presented in manuscript to the 1932 (York) Meeting of the Association and contained details of the replies received from South Africa, Australia, New Zealand, India, and the Far East, with replies received from the British Isles and the United States for purposes of comparison. The replies from Canada had not, at that time, been received; and since the Interim Report certain other replies to the questionnaire have been received from other parts of the Empire.

The sections which follow deal with the major parts of the British Empire in turn.

II. Dominion of New Zealand.

Dr. W. N Benson of the University of Otago, Dunedin, New Zealand, who was co-opted a member of the Committee and collected the replies to the questionnaire from his colleagues, summarises the position in New Zealand as follows :

'The four constituent colleges of New Zealand University are all concerned with the same prescriptions and the differences between the replies merely reflect different arrangements for dealing with the subject. The prescriptions are contained in the New Zealand University Calendar. Briefly Geography figures in the Entrance or Matriculation examination, in the Entrance Scholarship examination requiring one or two years further high school work. Examination of these prescriptions is conducted by University teachers, almost invariably the Professors of Geography in association with one or more assistants, usually University or Teachers' Training College lecturers. Economic Geography is also taught by a lecturer in the Department of Economics in each college, for the purposes of the B.Com. degree only, such requiring only one, or sometimes two, hours per week, unaccompanied by any laboratory work. Geolcgy in its general aspects as a subject for the B.A. course, first year work only, is taught in the Auckland and Wellington Colleges by the Professor of Geology, associated with a lecturer from the Teachers' Training College in Auckland and a lecturer from the Economics Department in Wellington. There has resulted from this the emphasis on the physical and economic side, without (unless it be in Auckland) any special attention to the human side. In the hopes of encouraging advanced study in Geography and the appointment of a teacher specialist in the subject, the University has approved courses for a second and third year in Geography for the B.A., but as yet provision for the teaching of such courses has not been made by any college. The several replies summarised are thus :—

AUCKLAND : Professor of Geology and associate lecturers from the Teachers' Training College are doing most of the B.A. first year Geography course ; Professor J. A. Bartrum, M.Sc., F.G.S. ; Lecturers, C. R. Laws, M.Sc., and — Jones, B.Sc. (Training College).

WELLINGTON : Professor C. A. Cotton, D.Sc., F.G.S. (Department of Geology) ; Miss Hilda R. Heine, M.A., Ph.D., for Economic Geography.

CHRISTCHURCH : R. S. Allan, M.Sc., Ph.D., Lecturer in Geology (not giving instruction in Geography every year) ; G. C. Billing, Lecturer in Economics Department, gives the Economic Geography course.

In addition, the giving of Economic Geography lectures in Auckland by a lecturer in the Department of Economics should be noted.

'It is worthy of remark that it is not possible to take Geography as a subject for the B.Sc. degree, nor to take both Geography and Geology as subjects for the B.A. degree on account of the overlapping in Physical Geography.'

Details of Auckland University College were supplied by Professor J. A. Bartrum (Professor of Geology), details of Victoria University College, Wellington, by Professor C. A. Cotton, and for Canterbury College, Christchurch, by Dr. R. S. Allan (Lecturer in Geology).

III. COMMONWEALTH OF AUSTRALIA.

The replies from Australian universities were collected by Dr. Charles Fenner, of the University of Adelaide. He summarises the position as follows :

'The attached schedule discloses the replies to the questionnaire submitted by the above Committee to the Universities of (1) Sydney, (2) Melbourne, (3) Adelaide, (4) Brisbane, (5) Perth, (6) Hobart.

'Summing up the position it may be said that, except in one instance, the teaching of Geography is not in an advanced position in the universities of Australia. The exception is the University of Sydney, where a complete and well-equipped department of Geography is in existence, carrying out a four-year course of work, including Honours, branching into the faculties of Science, Arts, and Commerce, and conducting research work.

'In other Australian universities there exist movements making for the progress of geographical teaching ; these come mainly from three directions : first, from departments of Commerce, which stress the need for the teaching of Economic Geography ; secondly, from departments of Geology, where it is felt that their physiographic teaching should develop into geographical work ; and thirdly, from the public and private schools of the various States, where teachers of geography feel the need for university teaching and guidance.

'The movement towards the extension of geographical teaching from a geological basis has advanced well in the University of Queensland, as reported by Professor H. C. Richards, and also in the University of Adelaide, where Sir Douglas Mawson has interested himself in the matter. In the latter case Geography is at present a one-year Arts subject ; in the former, progress has been held up on account of expense.

'In the Melbourne University the teaching of Economic Geography is on a sound basis, and there is some correlation with the Geology Department. There is no geographical teaching in Perth, and only a one-year course in Economic Geography in Hobart. Thus, apart from the University of

Sydney, no Australian university is doing geographical work at all comparable with that of the leading universities of Britain.'

IV. Union of South Africa.

Replies to the questionnaire from the Union of South Africa were collected by Professor J. H. Wellington of the University of Witwatersrand, Johannesburg. The position is shown in the schedule.

V. The Dominion of Canada.

The replies to the questionnaire from Canadian universities were collected by Dr. L. J. Burpee. Dr. Burpee summarises the position as follows :—

'It will be seen from the replies received that very little has yet been done in this direction (i.e. the establishment of Geography, in the universities). In the sense in which the question is meant, it must be said that so far there is no Department of Geography in any Canadian university. It will be noted that the University of British Columbia and the University of Montreal both report a Department of Geography but it would seem that for all practical purposes the situation is the same in these universities as in Toronto and McGill and most of the other universities, where Geography is more or less a course in the Department of Geology and the Department of Economics. It will be noticed that from Professor Innis' letter that Toronto University has for some time been feeling its way towards the establishment of a Department of Geography, but the time is not yet ripe. I think the same situation applies to several other Canadian universities, and probably after we have got through this period of depression some progress may be anticipated.'

The actual position is shown in the attached schedule.

VI. India and the Far East.

The questionnaire was sent to all the Indian and Far Eastern universities (i.e. including Singapore and Hong Kong) and replies were received from all those mentioned in the schedule.

VII. Summary.

For purposes of comparison, Professor Griffith of the University of Chicago obtained replies to the questionnaire from a number of representative universities in the United States.

It will be clear from the replies to the questionnaire that Geography does not yet occupy the important position in the curricula of the universities of the Dominions that it does in the universities of the Home Country, or in the universities of the United States. In the universities of Australia and New Zealand the subject is represented, and there is a remarkably strong department in the University of Sydney. In South Africa the subject is important, especially in the Universities of Witwatersrand and Pretoria.

In India the subject is growing in importance ; there is a specially strong department in the modern University of Rangoon.

The position in Canada, which cannot be said to have any full department of geography in its several universities, is a remarkable contrast to the United States and to the Home Country.

Document A.

Dear Sir,—On behalf of the Committee appointed by Section E (Geography) of the British Association at its Centenary Meeting held in London, September 23–30, 1931, to inquire into the position of Geography in the universities of the Empire, we enclose a short questionnaire relative to the position occupied by Geography in your University.

It will be of great assistance to us if you will be so good as to answer the questions as fully as possible and also add any other information bearing on this topic which you think would be of value.

(*signed*) C. B. Fawcett (*Chairman*).
L. Dudley Stamp (*Secretary*).

The Committee consists of the following : L. J. Burpee (Ottawa) ; W. N. Penson (Dunedin) ; F. Debenham (Cambridge) ; C. B. Fawcett (London), Chairman ; C. Fenner (Adelaide) ; Griffith Taylor (Chicago, late of Sydney, N.S.W.) ; L. Dudley Stamp (London, late of Rangoon), Secretary ; J. H. Wellington (Johannesburg), with power to co-opt.

Document B.

Questionnaire.

(1) What is the position of Geography as a subject—
- (*a*) in the Matriculation or other entrance examination ?
- (*b*) in Intermediate or other pre-graduation examinations ?
- (*c*) in the First Degree (Pass and/or Honours) and in what faculty or faculties ?
- (*d*) in Higher Degrees ?
- (*e*) in other qualifications recognised or awarded by the University (e.g. Diplomas) ?
- (*f*) as part of the training for Degrees in other subjects ?

(2) (*a*) Is there a Department of Geography ?
- (*b*) If so, in what faculty or faculties ?
- (*c*) Is Geography independent or combined with one or more other subjects in a joint Department ?

(3) What is the teaching staff in Geography ? Please give names and status.

(4) What, if any, members of the staffs of other departments teach Geography ? Please give names and status.

(5) What proportion, if any, of the work takes the form of laboratory work (in hours per week) ?

(6) Please give any other information which bears on the subject.

Replies should be sent as follows :—

From Canadian universities to Dr. L. J. Burpee, International Joint Commission, Ottawa.

From United States universities to Prof. Griffith Taylor, University of Chicago.

From Australian universities to Dr. C. Fenner, University of Adelaide.

From South African universities to Prof. J. H. Wellington, University of the Witwatersrand, Johannesburg.

From New Zealand institutions to Dr. W. N. Benson, University of Otago, Dunedin.

SOUTH AFRICA.

Questionnaire.	Pietermaritzburg.	Pretoria.	Stellenbosch.
1. Position of Geography			
(a) in Matric. or other entrance	Yes; optional S.L.C.	Yes; S.L.C. optional.	Yes; S.L.C. optional.
(b) Inter. or other pregrad.	No Inter.	No Inter.	No Inter. exam.
(c) First degree:			
Pass	Yes.	Yes.	Yes.
Honours	—	—	—
Faculty	Arts and Science.	Arts and Science.	Arts.
(d) Higher degrees	M.A., M.Sc., D.Sc., and D.Phil.	M.A., M.Sc., D.Sc.	M.A. and Doctorate.
(e) other qualifications	Subj. Natal Higher Edn. Dipl.	Subj. Higher Dipl. in Edn.	In B.Com. (compulsory).
(f) degrees in other subjects	Compulsory alt. with Hist. in Econ. degree.	Compulsory in Com. faculty 1st year.	Compulsory in degrees Hist., Economics, etc.
2. (a) Dept. of Geog.	Yes.	Yes.	Yes.
(b) In what faculty?	Arts, Science, Commerce.	Arts and Science.	Arts.
(c) Independent or combined dept.	Combined 1st year Geology.	Independent.	Independent.
3. Teaching Staff:			
Professor(s)	—	1 (F. E. Plummer).	1 (P. Sertou).
Reader(s)	—	—	—
Lecturer(s)	1 (R. M. Jehu).	1 (C. F. Hugo).	1 (D. J. Conradie).
Others	—	1 (C. H. Scheepers—Demonstr.)	—
4. Teachers of other Depts. teaching Geog.	None.	None.	For Teacher's Dipl.
5. What proportion of work is lab. work? Hours per week.	3 (1st, 2nd and 3rd years).	3 (1st year), 4 (2nd year), 6 (3rd year).	1 (1st year), 2 (2nd year), 2–3 (3rd year).
6. Other information	More staff needed but financial conditions against this.	—	—

SOUTH AFRICA.

Questionnaire.	Witwatersrand (Johannesburg).	Cape Town.
1. Position of Geography :		
(a) in Matric. or other entrance	Yes ; optional S.L.C.	Yes ? no data.
(b) Inter. or other pre-grad.	No Inter. exam.	—
(c) First degree :		
Pass	Yes.	No.
Honours	Yes.	—
Faculty	Arts and Science, and in B.Com.	—
(d) Higher degrees	M.A., D.Sc., etc.	—
(e) Other qualifications	Dipl. in Geog.	—
(f) Degrees in other subjects	Optional for Hist., Econ., Social Anthrop.	Part of B.Com. Degree, and Compulsory for Prim. Teacher's Cert.
2. (a) Dept. of Geog.	Yes.	No.
(b) In what faculty ?	Arts, Science, Commerce.	—
(c) Independent or combined Dept.	Independent.	—
3. Teaching staff :		
Professor(s)	1 (J. H. Wellington).	See 4.
Reader(s)	—	—
Lecturer(s)	1 (S. P. Jackson).	—
Others	—	—
4. Teachers of other Depts. teaching Geography.	None.	H. Hutchinson, Econ. Geog. for B. Com. ; J. F. Burger and E. G. Pells (Fac. of Edn.) for Teacher's Certif.
5. What proportion of work is lab. work ? Hours per week.	3 (1st year), 4 (2nd year), 5 (3rd year).	—
6. Other information	Hons. degree obtained after 1 or 2 yrs. special study after Pass degree. M.A., M.Sc., by Thesis.	—

CANADA.

Questionnaire.	Acadia, Wolfville, N.S.	Alberta.
1. Position of Geography:		
(*a*) in Matric. or other entrance	Yes.	Yes; optional.
(*b*) Inter. or other pre-grad.	No; only part of History.	No.
(*c*) First degree:		
Pass	No.	No.
Honours		
Faculty		
(*d*) Higher degrees	No.	No.
(*e*) Other qualifications	Training course for teachers, Com. Geog. in Com. Dept. of Horton Academy of the Univ.	—
(*f*) degrees in other subjects	Part of History course. Classical Geog. in study of Classics.	—
2. (*a*) Dept. of Geography	No.	—
(*b*) In what faculty?	—	—
(*c*) Independent or combined Dept.	Combined with History.	Dept. of Geology includes Physical Geog.
3. Teaching staff:		None.
Professor(s)	—	—
Reader(s)	—	—
Lecturer(s)	—	—
Others	—	—
4. Teachers of other Depts. teaching Geography.	Prof. R. S. Longley, Prof. T. W. Dadson (Dept. of History); W. H. Thompson (Dept. of Classics); J. Everett Moses (Commercial Dept.); D. Wright, L. H. Crandall (Horton Academy).	2 members of Dept. of Geology take some Physical Geog.
5. What proportion of work is lab. work? Hours per week.	None.	None.
6. Other information	—	Plan to establish Geog. under Dept. of Geology when conditions permit, until it is possible to develop Geog. independently.

CANADA.

Questionnaire.	Bishop's Univ. Lennoxville, Quebec.	British Columbia.
1. Position of Geography :		
(*a*) in Matric or other entrance	Yes.	Optional subject.
(*b*) Inter. or other pre-grad.	No.	Yes. B.A. or Commercial.
(*c*) First degree :		
Pass	No.	Arts and Commerce.
Honours		
Faculty		
(*d*) Higher degrees	—	M.A.
(*e*) Other qualifications	Dept. of History gives some attention to Geog.	Subj. for Public Health Dipl.
(*f*) Degrees in other subjects	—	B.A.Sc. in Nursing and Health, but crowded out by professional courses.
2. (*a*) Dept. of Geography	No.	Yes.
(*b*) in what faculty ?	—	Arts.
(*c*) Independent or combined Dept.	—	Combined with Geology.
3. Teaching staff :		
Professor(s)	—	2 (R. W. Brock, S. J. Schofield).
Reader(s)	—	—
Lecturer(s)	—	—
Others	—	—
4. Teachers of other Depts. teaching Geog.	—	J. Friend Day (Asst. Prof. of Econ. and Commerce).
5. What proportion of work is lab. work ? Hours per week.	—	one-third instructed lab. work.
6. Other information	—	Lack of funds has prevented Dept. from being brought up to its projected strength.

CANADA.

Questionnaire.	Dalhousie (Halifax).	Laval, Quebec.	Manitoba.	McGill (Montreal).
1. Position of Geography :				
(a) in Matric. or other entrance.	No.	Yes. Special Exam.	No.	Physical (Junior Matric. only recognised as entrance by Sch. of Agric.).
(b) Inter. or other pre-grad.	No.	Yes.	No.	—
(c) First degree :				
Pass	—		—	—
Honours	No.	Yes. Arts.	No.	—
Faculty	—		—	—
(d) Higher degrees	No.	No.	—	—
(e) Other qualifications	—	B.A., B.L., B.S. degrees.	—	—
(f) Degrees in other subjects.	—	No.	—	Geog. only in Econ. and Geol. courses.
2. (a) Dept. of Geography	No.	No.	No.	No.
(b) In what faculty ?	—	—	—	—
(c) Independent or combined Dept.	—	—	—	—
3. What is the teaching staff in Geography ?	None.	—	—	None.
Professor(s)	—	—	—	—
Reader(s)	—	—	—	—
Lecturer(s)	—	—	—	—
Others	—	—	—	—
4. Teachers of other Depts. teaching Geog.	None.	—	—	—
5. What proportion of the work is lab. work ? Hours per week.	None.	None.	—	—
6. Other information	—	—	—	—

CANADA.

Questionnaire.	McMaster, Hamilton (Ont.).	Montreal.
1. Position of Geography:		
(a) in Matric. or other entrance	—	Subj. in 17 Classical colleges (French type).
(b) Inter. or other pre-grad.	—	—
(c) First degree:		
Pass	No.	B.A.
Honours		
Faculty		
(d) Higher degrees	—	—
(e) Other qualifications	—	—
(f) Degrees in other subjects	See below.	—
2. (a) Dept. of Geography	No.	Geog. taught in Fac. of Letters, Sch. of Social, Econ. and Polit. Sci., and Fac. of Commerce.
(b) In what faculty?	—	
(c) Independent or combined Dept.	—	
3. Teaching staff:		
Professor(s)	—	—
Reader(s)	—	—
Lecturer(s)	—	—
Others	—	—
4. Teachers of other Depts. teaching Geog.	3 (Prof. of Polit. Econ. takes Econ. and Com. Geog.; Prof. of Geol. takes Physiography; Prof. Taylor lectures on Population and Sociology).	3 (M. Yves Tessier-Lavigne, Fac. of Letters and Sch. of Soc., Econ. and Polit. Sci. M. Francois Vezina and M. Benoit Brouillette, Faculty of Commerce).
5. What proportion of work is lab. work? Hours per week.	—	None.
6. Other information	—	—

CANADA.

Questionnaire.	New Brunswick.	King's College, Halifax.
1. Position of Geography :		
(a) in Matric. or other entrance	Combined with History on 1 paper.	No Geography taught.
(b) Inter. or other pre-grad.	No.	
(c) First degree :		
Pass	No.	
Honours	No.	
Faculty	No.	
(d) Higher degrees	No.	
(e) Other qualifications	No.	
(f) Degrees in other subjects	Incidental.	
2. (a) Dept. of Geography	No.	
(b) In what faculty ?	—	
(c) Independent or combined Dept.	'As above.'	
3. Teaching staff :	None.	
Professor(s)		
Reader(s)		
Lecturer(s)		
Others		
4. Teachers of other Depts. teaching Geog.	Incidentally by Profs. of History and Geology.	
5. What proportion of work is lab. work ? Hours per week.	None.	
6. Other information	Practically no Geog. taught in Univ.	

Questionnaire.	Queen's, Kingston, Ont.	Saskatchewan.	Toronto.
1. Position of Geography :			
(a) in Matric. or other entrance	No place in curriculum.	—	—
(b) Inter. or other pre-grad.	—	—	—
(c) First degree :			
Pass	—	—	1st year Com. and Finance take introd. course ; 4th years take advanced Econ. Geog. as optional.
Honours	—	—	
Faculty	—	—	
(d) Higher degrees	—	—	—
(e) Other qualifications	—	—	—
(f) Degrees in other subjects	—	Dept. of Geol. gives some physical, Dept. of Econ. some econ.	—
2. (a) Dept. of Geography	—	No.	Not yet.
(b) In what faculty ?	—	—	—
(c) Independent or combined Dept.	—	—	Combined with Geology.
3. Teaching staff :			
Professor(s)	—	None.	H. A. Innis (Associate Prof. of Econ. Geog.).
Reader(s)	—	—	
Lecturer(s)	—	—	
Others	—	—	—
4. Teachers of other Depts. teaching Geog.	—	Depts. of Geology and Economics.	Prof. G. E. Jackson and Prof. Innis.
5. What proportion of work is lab. work ? Hours per week.	—	—	—
6. Other information	—	In favour of Chair but no funds available.	Dept. of Geog. would have been set up had it not been for trade depression. Prof. of Education gives some Geog. instruction to trainees for teaching.

CANADA.

Questionnaire.	Western Ontario.	Trinity Coll., Toronto, Victoria Univ., Toronto.
1. Position of Geography :		
(*a*) in Matric. or other entrance	Only in pre-Matric. (Lower School).	(See Toronto University.)
(*b*) Inter. or other pre-grad.	No.	
(*c*) First degree :		
Pass	No.	
Honours	No.	
Faculty	No.	
(*d*) Higher degrees	None.	
(*e*) Other qualifications	None.	
(*f*) Degrees in other subjects	Dept. of Econ. and Polit. Sci. takes Econ. Geog. as one subject.	
2. (*a*) Dept. of Geography	No.	
(*b*) In what faculty ?		
(*c*) Independent or combined Dept.		
3. Teaching staff :		
Professor(s)	None.	
Reader(s)	None.	
Lecturer(s)	None.	
Others	None.	
4. Teachers of other Dept. teaching Geog.	M. K. Inman (Asst. Prof. Econ. and Polit. Sci.).	
5. What proportion of work is lab. work ? Hours per week.	None.	
6 Other information	—	

INDIA AND THE FAR EAST.

Questionnaire.	Agra.	Aligarh.	Allahabad.
1. Position of Geography :			
(*a*) in Matric. or other entrance	—	Yes.	No exam.
(*b*) Inter. or other pre-grad.	—	—	No exam.
(*c*) First degree	Yes.	No particulars received.	Yes.
Pass	—		—
Honours	—		—
Faculty	Arts and in 3 colleges Commerce.		Commerce (compulsory).
(*d*) Higher degrees	—	—	—
(*e*) Other qualifications	—	—	—
(*f*) Degrees in other subjects	—	—	—
2. (*a*) Dept. of Geography	—	Yes.	No.
(*b*) In what faculty?	—	—	Commerce.
(*c*) Independent or combined dept.	—	—	Combined with Dept. of Commerce.
3. Teaching staff :			
Professor(s)	—	—	—
Reader(s)	—	1 (I. R. Khan).	—
Lecturer(s)	—	1 (S. Q. Ahmad).	1 (R. N. Dube).
Others	—	—	—
4. Teachers of other Depts. teaching Geography.	—	—	—
5. What proportion of work is lab. work? Hours per week.	—	—	—
6. Other information	—	—	—

Note : No replies received from Benares, Bombay or Calcutta, which have, however, no departments or staff in geography.

INDIA AND THE FAR EAST.

Questionnaire.	Dacca.	Delhi.	Lucknow.	Madras.
1. Position of Geography :				
(*a*) In Matric. or other entrance	—	—	Not a subject.	Yes. Compulsory.
(*b*) Inter. or other pre-grad.	—	—	Univ. provides post-Inter. work only.	Yes. Optional.
(*c*) First degree	B.Com. (1 paper)	—		Yes.
Pass	—	—	—	No.
Honours	—	—	—	Arts and Science.
Faculty	Commerce	—	—	None.
(*d*) Higher degrees	—	—	—	Diploma.
(*e*) Other qualifications	—	—	—	Teachers' Training Course
(*f*) Degrees in other subjects	—	—	—	specialises :n Geography.
2. (*a*) Dept. of Geography	—	—	—	Projected.
(*b*) In what faculty ?	—	—	—	Arts.
(*c*) Independent or combined Dept.	—	—	—	Independent.
3. Teaching Staff :				
Professors(s)	—	—	—	—
Reader(s)	—	—	—	1 (to be appointed).
Lecturer(s)	—	—	—	2 (to be appointed).
Others	—	—	—	—
4. Teachers of other Depts. teaching Geography.	—	—	—	None.
5. What proportion of work is lab. work? Hours per week.	—	—	—	—
6. Other information	—	—	—	Subj. no place until recently. Increasing interest being shown by Univ. authorities.

INDIA AND THE FAR EAST.

Questionnaire.	Mysore.	Nagpur.	Osmania (Hyderabad).	Patna.
1. Position of Geography :				
(a) in Matric. or other entrance	Yes. Compulsory S.S.L.C.	No exam.	Yes. Compulsory.	Yes. Compulsory.
(b) Inter. or other pre-grad.	Not a subject.	Recently recognised.	Not a subject.	Yes.
(c) First degree :				
Pass	—	—	—	Yes.
Honours	—	—	—	—
Faculty	—	—	—	Arts:
(d) Higher degrees	—	—	—	No.
(e) Other qualifications	—	—	—	—
(f) Degrees in other subjects	—	—	—	Subj. in Dipl. in Edn. and B.Ed.
2. (a) Dept. of Geography	—	—	—	No.
(b) In what faculty ?	—	—	—	—
(c) Independent or combined Dept.	—	—	—	—
3. Teaching staff :				
Professor(s)	—	—	—	—
Reader(s)	—	—	—	—
Lecturer(s)	—	—	—	1 (S. C. Chatterji).
Others	—	—	—	1 (S. N. Chatterji).
4. Teachers of other depts. teaching Geography.	—	—	—	2 *may* teach.
5. What proportion of work is lab. work ? Hours per week.	—	—	—	2 (1st year), 3 (2nd year).
6. Other information	—	—	—	Training in Surveying.

INDIA AND THE FAR EAST.

Questionnaire.	Punjab.	Rangoon.	Andhra (Waltair).
1. Position of Geography :			
(a) in Matric. or other entrance.	Yes.	Yes. Optional.	Yes. Compulsory.
(b) Inter. or other pre-grad.	—	Yes. Optional. Very popular.	Yes.
(c) First degree :			
Pass	—	Yes. Arts and Science.	No.
Honours	—	Yes. Arts.	No.
Faculty	—	Arts and Science.	—
(d) Higher degrees	—	M.A.	No.
(e) Other qualifications	—	None.	None.
(f) Degrees in other subjects	—	Optional in Hist., Maths., Econ., Languages, Geol., etc.	Subj. for B.Ed. (methods of teaching).
2. (a) Dept. of Geography	—	Yes.	No.
(b) In what faculty ?	—	—	—
(c) Independent or combined Dept.	—	Combined with Geology.	—
3. Teaching Staff :			
Professor(s)	—	1 (C. G. Beasley).	—
Reader(s)	—	—	—
Lecturer(s)	—	2 (1 Geog., 1 Geog. and Geol. —S. P. Chatterjee).	1. (V. Jagannadha Rao in Govt. Training College, Rajahmundry).
Others	—	2 (Demonstr., S. Ramamirthan, & H. Clayton).	—
4. Teachers of other Depts. teaching Geography.	—	Econ. Dept., by E. H. Solomon.	None.
5. What proportion of work is lab. work? Hours per week.	—	2 (Inter.), 4 (Degree—minimum).	2 in B.Ed. class.
6. Other information	—	Separate Boards of Studies in Geog. and Geol. Departmental independence characteristic of organisation. Departmental grants for research.	—

INDIA AND THE FAR EAST.

Questionnaire.	Hong Kong.	Raffles College, Singapore.	University College, Ceylon.
1. Position of Geography :			
(a) in Matric. or other entrance	Yes. Optional.	—	Yes.
(b) Inter. or other pre-grad.	Yes. Dept. Commerce.	—	—
(c) First degree :			
Pass	No.	No particulars.	No particulars.
Honours	No.		
Faculty	—		
(d) Higher degrees	No.	—	—
(e) Other qualifications	No.	—	—
(e) Degrees in other subjects	Optional in Ethics and Phil., Soc. Sci., Teachers' Training.	—	—
2. (a) Dept. of Geography	No.	Yes.	—
(b) In what faculty ?	—	—	—
(c) Independent or combined Dept.	Combined with Dept. of Commerce.	—	—
3. Teaching Staff :			
Professor(s)	—	1 (H. Amon).	—
Reader(s)	—	—	—
Lecturer(s)	1 (Father D. J. Finn).	1 (T. W. Morray).	1 (L. McD. Robison).
Others	—	—	—
4. Teachers of other Depts. teaching Geography.	None.	—	—
5. What proportion of work is lab. work? Hours per week.	Nothing definite, but pract. work done in connection with Geog. Soc.	—	—
6. Other information	—	—	—

AUSTRALIA.

Questionnaire.	Adelaide.	Brisbane.	Hobart.
1. Position of Geography:			
(*a*) in Matric. or other entrance	Yes; optional.	Yes; optional. Compulsory Eng. Fac.	Yes.
(*b*) Inter. or other pre-grad.	Yes; also Leaving.	Yes; optional in Junior and Senior.	Yes; and Leaving.
(*c*) First degree:			
Pass	Yes.	Yes; compulsory Comm. and Agric.	One-year course in Econ.
Honours	—	—	—
Faculty	Arts and Econ.	Arts and Commerce.	Economics.
(*d*) Higher degrees	No.	No.	None.
(*e*) Other qualifications	None.	None.	None.
(*f*) Degrees in other subjects	No.	Compulsory in Hist. and Econ. Hons.	No.
2. (*a*) Dept. of Geography	No.	No.	No.
(*b*) In what faculty?	Economics.	—	—
(*c*) Independent or combined Dept.	Independent.	Combined Dept. Economics.	—
3. Teaching staff:			
Professor(s)	—	—	—
Reader(s)	—	—	—
Lecturer(s)	1 (Charles Fenner) part time.	1 (J. L. K. Gifford) part time.	—
Others	—	—	Prof. T. Hytten lectures in Econ. Geog.
4. Teachers of other Depts. teaching Geography.	None.	Mr. Gifford also lectures in Econ. and Hist. Phys. Geog. in Dept. Geol.	None.
5. What proportion of work is lab. work? Hours per week.	2 lectures per week. 3 ½-day excursions per annum.	None.	None.
6. Other information	Introduced in 1930 as a one-year subject. Physiography also included in Geol. course.	Efforts on foot to extend Geog. teaching in Dept. of Geol.	—

Questionnaire.	Melbourne.	Perth.	Sydney.
1. Position of Geography :			
(*a*) in Matric. or other entrance	Yes ; sci. subject	Yes.	Yes.
(*b*) Inter. or other pre-grad.	Yes.	Yes ; Junior and Leaving	Yes ; Inter. and L.C.S.
(*c*) First degree :			
Pass	1-year subj. in B.Com.	No.	Yes.
Honours	—	—	Yes.
Faculty	Commerce.	—	Arts and Science.
(*d*) Higher degrees . .	None.	None.	M.Sc., D.Sc.
(*e*) Other qualifications .	None.	None.	—
(*f*) Degrees in other subjects	None.	None.	Part of Dipl. and degree in Econ.
2. (*a*) Dept. of Geography . . .	No.	No.	Yes.
(*b*) In what faculty ? . .	Commerce.	—	Sci., but B.A. Hons. in Arts.
(*c*) Independent or combined Dept.	Combined with Commerce.	—	Independent.
3. Teaching Staff :			
Professor(s) . . .	Ass. Prof. Commerce (G. L. Wood) in charge of Econ. Geog. ; F. O. Barnett, Miss A. Nicholls (Geology).	—	1 (J. Macdonald Holmes).
Reader(s)		—	—
Lecturer(s) . . .		—	—
Others		—	2 Demonst. (J. Andrews and Miss Back) ; also stud. Demonst.
4. Teachers of other Depts. teaching Geography.	E. S. Hills (Geol. dept.) lectures on Physiography.	—	None.
5. What proportion of work is lab. work ? Hours per week.	None.	—	3 (1st year), 6 (2nd year), 9 (3rd year). Hons. full time and field work.
6. Other information . . .	Physiography with field and lab. work in Geology, Parts I and II.	Physiography with field work in Geol. courses.	Matric. status and 3-year courses since 1930. Well established.

EMPIRE SOIL RESOURCES.

Report of Committee appointed to co-operate with the Imperial Soil Bureau to examine the soil resources of the Empire (Sir JOHN RUSSELL, O.B.E., F.R.S., *Chairman*; Mr. G. V. JACKS, *Secretary*; Prof. C. B. FAWCETT, Mr. H. KING, Dr. L. DUDLEY STAMP, Mr. A. STEVENS, Dr. S. W. WOOLDRIDGE, Dr. E. M. CROWTHER, Dr. W. G. OGG, Prof. G. W. ROBINSON).

THE Committee has secured the assistance of several noted geographers, who are now engaged in collecting climatic and ecological data of the different countries of the British Empire. Corresponding maps are being prepared, and it is hoped that a fairly complete series will be ready by the end of the year. The Committee has held one meeting, in conjunction with its collaborators, at which progress was reviewed and a programme outlined for the continuation of the work.

STRESSES IN OVERSTRAINED MATERIALS.

Interim Report of Committee on Stresses in Overstrained Materials (Sir HENRY FOWLER, K.B.E., *Chairman*; Dr. J. G. DOCHERTY, *Secretary*; Prof. G. COOK, Prof. B. P. HAIGH, Mr. J. S. WILSON).

THE following interim report is submitted:

'The work of the Committee on the yield point and on stress distributions in the initial stages of plastic yield in a variety of cases is proceeding. It is hoped that a full report of these experiments will be submitted in 1934.'

The Committee ask to be reappointed for another year.

ELECTRICAL TERMS AND DEFINITIONS.

Report of Committee on Electrical Terms and Definitions (Prof. Sir J. B. HENDERSON, *Chairman*; Prof. F. G. BAILY and Prof. G. W. O. HOWE, *Secretaries*; Prof. W. CRAMP, Prof. W. H. ECCLES, F.R.S., Prof. C. L. FORTESCUE, Sir R. GLAZEBROOK, K.C.B., F.R.S., Prof. A. E. KENNELLY, Prof. E. W. MARCHANT, Sir FRANK SMITH, K.C.B., C.B.E., Sec. R.S., Prof. L. R. WILBERFORCE).

IN last year's report reference was made to the undesirability of making a technical report pending the decision of the Symbols, Units and Nomenclature (S.U.N.) Commission of the International Union of Physics which had just been constituted.

This Commission has reported, and this report goes a long way to remove the difficulties our Committee had encountered. As further reports of the above Symbols, Units and Nomenclature Commission are expected, we ask for reappointment.

The Committee ask for reappointment without grant.

EARTH PRESSURES.

Eighth Interim Report of Committee on Earth Pressures (Mr. F. E. WENTWORTH-SHEILDS, *Chairman*; Dr. J. S. OWENS, *Secretary*; Prof. G. COOK, Mr. T. E. N. FARGHER, Prof. A. R. FULTON, Prof. F. C. LEA, Prof. R. V. SOUTHWELL, F.R.S., Dr. R. E. STRADLING, Dr. W. N. THOMAS, Mr. E. G. WALKER, Mr. J. S. WILSON).

SINCE the Committee's last report, a meeting was held at Garston on June 22, 1933, when the Committee had the advantage of meeting Prof. Jenkin and hearing from him an account of the work he has done during the past year. A short report from him is appended.

His work, of which the Committee would again express high appreciation, has been of great importance. The work has consisted almost entirely of investigations and experiments on the mechanical properties of clay, the experiments being carried out with apparatus devised by him. It is hoped that these investigations and experiments will lead to an understanding of the fundamental principles of the mechanics of clay, and that it will then be possible to estimate the forces exerted by clay, used, for instance, as a foundation of a structure or as backing for a retaining wall.

The Committee would endorse Prof. Jenkin's conclusion that, although no definite results have been reached so far, the experiments are working well, and a promising theory is being worked out.

They recommend that his and their work be carried on for a further period.

REPORT FOR THE BRITISH ASSOCIATION EARTH PRESSURES COMMITTEE.

May 15, 1933.

Since my report dated July 1, 1932, the work on the mechanics of clay has been carried on continuously.

The filter press has been improved so that samples of air-free clay can now be prepared under any load up to 1,000 lb. (100 lb. per sq. in. in the largest cylinder). The pressure/moisture curve for China clay has been determined with this press. The result was quite unexpected: the moisture left in the clay is found to depend much more on the way the clay is handled than on the pressure. Rotating the piston in the press greatly reduced the water content, and rotation in alternate directions produces a still greater reduction in the water content.

An apparatus for measuring conjugate pressures on clay cylinders has been made and a full series of tests with it carried out. The results were again unexpected. It is found that the hydraulic conjugate pressure is transmitted through the clay in a few seconds by the water in the clay, so that it has no effect; the compression strengths are not altered by the presence of the hydraulic pressures. Tests were made with positive conjugate pressures up to about 1 atmosphere, and also with negative pressures approaching 1 atmosphere.

This apparatus has also been used to measure the compression strengths of clays of all moisture contents, and a complete curve of strength against moisture content has been plotted.

To extend this curve into the region of partially dry clay—i.e. clay into which air has penetrated—a simple compression testing machine has been

made suitable for applying the larger loads needed. The tests with this apparatus are almost complete.

To enable automatic records of compression load/strain curves to be obtained, and particularly to enable hysteresis loops to be recorded, the shear apparatus, referred to in the last report, has been slightly added to. With the new additions a very large number of records have been made on clays of various water contents, and some particularly interesting experiments have been made on clay tested under water and under oil. This 'hysteresis loop apparatus' produces records on smoked glass, which are varnished and stored.

At the present time a full investigation is being made on shear strengths in the shear apparatus. One of the many difficulties is that water is often extruded from the clay during the test. The cause of this extrusion is the point under investigation at the moment.

A good deal of thought and time has been spent on the design of a kneading apparatus which is wanted to mix the clay produced in the press so as to destroy any possible lamination. Some interesting results have been obtained, but no method has yet been found by which clay can be kneaded without introducing air.

All these experiments are valueless unless they lead to the understanding of the fundamental principles of the mechanics of clay. They are sufficient to show that none of the existing theories are tenable, and they all appear at present to point to an explanation which is fundamentally very simple, though disguised by many subsidiary effects. All the work at present is aimed at checking the accuracy of this hypothesis. Though there are many difficulties, none of them appear to be insuperable. The great trouble of endless creep has not appeared in any of the tests, all of which give definite results.

Conclusion.—Though no definite results have been reached so far, the experiments are working well, and a promising theory is being worked out.

C. F. Jenkin.

BRITISH SOMALILAND.

Report of Committee appointed to make a preliminary survey of some reported archæological sites in British Somaliland (Dr. A. C. Haddon, F.R.S., *Chairman*; Mr. R. U. Sayce, *Secretary*; Prof. J. L. Myres, F.B.A.).

The Committee was appointed at the Bristol Meeting in 1930, to enable Dr. L. S. B. Leakey to visit Somaliland and make preliminary examination of some reported archæological sites. Dr. Leakey was, however, prevented from going to Somaliland, either on his journey to Kenya Colony or on his way home; and has accordingly refunded the grant.

DERBYSHIRE CAVES.

Eleventh Interim Report of Committee appointed to co-operate with a Committee of the Royal Anthropological Institute in the exploration of caves in the Derbyshire district (Mr. M. C. BURKITT, *Chairman*; Dr. R. V. FAVELL, *Secretary*; Mr. A. LESLIE ARMSTRONG, Prof. H. J. FLEURE, Miss D. A. E. GARROD, Dr. J. WILFRID JACKSON, Prof. L. S. PALMER, Mr. H. J. E. PEAKE).

No new excavation work has been undertaken by the Committee during the current year, but the excavation of the Pin Hole Cave, Creswell Crags, has been steadily advanced by Mr. Leslie Armstrong, F.S.A., who reports as follows:

'During the autumn of 1932 work was concentrated upon the depressions in the floor of the passage on the east side of the main chamber, referred to in the report for 1932. Removal of the breccia over the whole area of the passage and the trefoil-shaped terminal chamber revealed four large cavities in the rock floor, one of which coincided with the width of the passage and extended 7 ft. along it. These were entirely filled with cave earth to a depth of 2 ft. 6 in. overlying sterile red sand. The cave earth was of Mousterian (1) age and yielded examples of the usual fauna, of which the most interesting specimens are the greater portion of the skull and lower jaw of a young mammoth with complete dentition, and two large fragments of the lower jaw of giant deer. Human occupation of the large cavity was demonstrated by a small but well-preserved hearth and the presence of a stone pounder, animal bones (split and charred), and crude artifacts of quartzite and crystalline stalagmite. Similar tools were recovered from the smaller cavities at the rear of the chamber. The most important finds in this level were several worked bone tools, including a bone knife and two awls. The red sand which underlies the cave earth was removed to a depth of 2 ft. and carefully sieved but, with the exception of the uppermost layer, proved to be entirely sterile and to have been introduced by water—probably during the original formation of the cave.

'Upon completion of the work in the east passage attention was turned to the large inner chamber of the cave, where operations had been suspended at the 12-ft. level in order to facilitate the excavation of the passage. This has now been completely excavated to the base—a total depth of 17 ft., of which the lowest 1 ft. 6 in. was entirely sterile and consisted of red sand, similar to that found in the passage cavities and previous sections of the main cave.

'The layer of fallen slabs which, throughout the cave, has so consistently marked the division between the Mousterian (1) and Mousterian (2) levels was found to be exceptionally thick and to include several massive slabs of tabular limestone. The underlying cave earth (Mousterian (1) in age) was also interspersed throughout by rocks and fragments of limestone, many of them of large size and entailing considerable labour in their removal, despite the disintegration which is common to all rocks and also to the cave walls at this level.

'The presence of so many rocks no doubt rendered this portion of the cave unsuitable for general occupation, and, in consequence, the remains recovered there in the Mousterian (1) zone have been less numerous than elsewhere in the cave. They include, however, a superb side scraper of flint and a number of quartzite fragments, split bones, etc.

'Work is now proceeding at the rear of the main chamber, where the width of the cave gradually contracts to a mere passage. It is hoped that the section under examination will be excavated down to the base level before the proposed visit to the cave by Section H during the forthcoming meeting at Leicester, in which case the complete stratification of the cave deposits, 17 ft. in thickness, will be exposed to view.'

Since the York Meeting, the bone upon which a masked human figure is engraved, and also the engraved mammoth ivory lance point, have been presented to the British Museum. The most important artifacts and a characteristic group of associated objects, faunal remains, etc., have been placed in the County Museum, Derby, in accordance with the decision of the Committee.

The Committee desires to be reappointed, and makes request for a further grant to enable the work at Creswell to be completed.

M. C. BURKITT, *Chairman.*
R. VERNON FAVELL, *Secretary.*

DISTRIBUTION OF BRONZE AGE IMPLEMENTS.

Report of Committee appointed to report on the Distribution of Bronze Age Implements (Prof. J. L. MYRES, F.B.A., *Chairman* ; Mr. H. J. E. PEAKE, *Secretary* ; Mr. A. LESLIE ARMSTRONG ; Mr. H. BALFOUR, F.R.S. ; Mr. L. H. DUDLEY BUXTON ; Prof. V. GORDON CHILDE ; Mr. O. G. S. CRAWFORD ; Prof. H. J. FLEURE ; Dr. CYRIL FOX).

IT is now twenty years since this Committee was appointed at the Birmingham Meeting in 1913. Hitherto the Committee has been engaged in compiling an illustrated card catalogue of all the 'Metal objects of the Bronze Age' in museums and private collections in the British Isles, and it is able to report that, with insignificant exceptions, all the specimens in England and Wales have been drawn, measured and described, and it is hoped that by the time that the Association meets in Leicester all the cards will have been stored in the drawers of the cabinet, which is being housed for the Association by the Society of Antiquaries.

At an early date it was found that if strict uniformity was to be preserved, all the cards should be prepared by one draughtsman. For this purpose the services of Mr. C. H. Howell were engaged, and retained until a few years ago, when the work, then nearing completion, became too intermittent to necessitate the services of a whole-time officer. Since then the cards have been prepared by Miss L. Chitty and Mrs. Michell-Clarke. While the funds necessary for the remuneration of these draughtsmen have been partly supplied by donations from generous patrons, a large part has been received from grants made to the Committee by the Association. The balance from these grants became exhausted before the end of 1932, since which date Mrs. Michell-Clarke has very kindly completed the work of drawing the specimens at the British Museum free of charge. Thus, the Committee believes, it has full information respecting all the metal objects of the Bronze Age in England and Wales, excepting the specimens of foreign origin in the British Museum, the Ashmolean and the Museum at York. In addition, it has a complete series of cards from the Isle of Man and the Channel Islands, cards for the majority of the specimens in Scotland

and of a considerable number from Ireland, as well as of those in the Harvard Museum and of the early specimens in the Museum of Copenhagen.

When the catalogue was first projected, the Committee hoped that, with international co-operation, it would have been possible to extend this catalogue so that it would cover the whole of Europe and the adjacent lands. With a view to thus widening the scope of this work, the Secretary attended a Meeting of the Association Française at Le Havre in July 1914, where he had an opportunity of bringing the matter to the notice of its Anthropological Section. Though much interest in the project was expressed, the mobilisation of the French army on the following day prevented for a time any help from this direction. Last year the Secretary brought the matter before the International Congress for Prehistoric and Protohistoric Sciences, and took representatives of France, Germany and other countries to see the catalogue. So far, however, no movement for extending the work upon the continent has been apparent.

The Committee asks to be reappointed, to make recommendations for the maintenance of the catalogue and for future work.

The Committee has considered the situation resulting from the virtual completion of the catalogue for England and Wales, and for the consequent need for a change of procedure in order to deal with accessions for the future. Without such provision the catalogue will rapidly become antiquated. The catalogue is now housed by the Society of Antiquaries, but without provision for accessions ; and it does not seem likely that the Society of Antiquaries would make such provision.

The Committee recommends that the best permanent repository for the catalogue, and for the incompleted records for Scotland and Ireland, would be the British Museum, provided that arrangements can be made for systematic record of accessions. In the event of an independent survey being made of the bronze implements of Scotland and of Northern Ireland, the Committee recommends that items should be duplicated for exchange between the national catalogues of those countries and the Committee's catalogue.

The Committee recommends that if this destination of the catalogue is approved, the Chairman and Secretary should be authorised to discuss the matter with the Director of the British Museum, and to report to the Organising Committee of Section H.

KENT'S CAVERN, TORQUAY.

Report of Committee appointed to co-operate with the Torquay Natural History Society in investigating Kent's Cavern (Sir A. KEITH, F.R.S., *Chairman* ; Prof. J. L. MYRES, F.B.A., *Secretary* ; Mr. M. C. BURKITT, Dr. R. V. FAVELL, Mr. G. A. GARFITT, Miss D. A. E. GARROD, Mr. LACAILLE).

THE following report has been received from the excavators, Messrs. F. Beynon and Arthur H. Ogilvie :

' Excavation in the vestibule adjoining the northern entrance to Kent's Cavern was begun on October 3, 1932, and on April 24, 1933, was adjourned to the next winter season.

' Work began by digging a trench 24 ft. long by 3 ft. wide alongside the

eastern wall of the chamber up to the entrance door. The surface of the present floor there is 5 ft. 9 in. below the level of the original granular stalagmitic floor, and the trench attained a depth of 1 ft. 6 in. at the inner end up to 5 ft. at the entrance, the depth being determined when bed-rock was reached. After sorting all excavated material this trench was refilled, and three other wide trenches at right angles to the first were made, beginning at the entrance to the cavern transversely across the passage way. Each portion was filled up as soon as bed-rock was encountered, that immediately inside the door being 7 ft. deep, the next 8 ft., and the third 4 ft. 3 in. deep. It is interesting to note that the foregoing shows that the opening into the cave at this point must have been at least three times the height that it appeared when operations were begun early last century.

'Specimens of the usual cave fauna were found, including a right ramus of the lower jaw of a hyena, with its condyle and lower border ungnawed; it is most unusual to find one in this state in Kent's Cavern, as the hyena always seems to have left as little as possible of the remains of his deceased relatives.

'The discovery of the bony base of a rhinoceros horn is also of interest.

'Artifacts found included a fine bone awl and two similar but less noticeable specimens; also small tines of deers' antlers which seem to have been used as borers. Flint flakes and chips were met with occasionally, and encourage the belief that more finished flint-work, of which they are the remains, will be found not far away next season.' (Signed) F. Beynon, Arthur H. Ogilvie.

The Committee asks to be reappointed, with a small grant for the employment of a labourer to remove excavated material after examination. The expenditure on labourer's wages during the period covered by this report amounted to £8 13*s.* 9*d.*, of which £5 was met by the British Association's grant.

SUMERIAN COPPER.

Fifth Interim Report, by Dr. C. H. Desch, F.R.S., *of Committee appointed to report on the Probable Sources of the Supply of Copper used by the Sumerians* (Mr. H. J. E. Peake, *Chairman*; Dr. C. H. Desch, F.R.S., *Secretary*; Mr. H. Balfour, F.R.S.; Mr. L. H. Dudley Buxton; Prof. V. Gordon Childe; Mr. O. Davies; Prof. H. J. Fleure; Sir Flinders Petrie, F.R.S.; Dr. R. H. Rastall).

Since the publication of the last Report the analytical work of the Committee has been transferred from the University of Sheffield to the National Physical Laboratory. Specimens have been received from a number of sites, together with a few ores. The presence of arsenic in relatively high proportion in several objects of early date has made it necessary to regard this, like nickel, as a key element, which should assist in the location of the source of the original copper. Unfortunately, the information as to the actual composition of copper ores in the regions now being studied is very scanty. As a rule, the statements in works of reference, and even in geological monographs, are confined to a record of the occurrence of copper, together with a figure expressing the average richness of the ore, with statistics of production where the mine has been recently worked. It is

rare to find any mention of the presence of accessory elements. Such specimens as have been received for examination, except for the native coppers described in the First Report, have been from deep-seated deposits of pyrites, whilst the ancient copper was undoubtedly derived mainly from oxidised outcrops. Some specimens have proved to be slags from comparatively modern workings. The search for ores is being pursued, and the Committee is indebted to Sir Arnold Wilson for his assistance in procuring them and in advising as to possible sources. Arsenical copper ores, sometimes containing nickel, are found in Armenia, south of Lake Van, and in Anatolia, at Yenikoi, south of the Sea of Marmora, whilst the ore at Kastamouni, near to the Black Sea, is known to contain nickel. The known occurrences have been mapped, and the region within which such mixed ores, containing both arsenic and nickel, may occur appears to form a band extending through Anatolia, Armenia and Azerbaijan, but sources farther afield cannot at present be excluded.

A piece of thin metal from Professor Langdon, from the 1930 excavations at Kish, reported as of date 3200 B.C., gave 95·17 per cent. copper, 0·08 nickel, 4·60 arsenic, and 0·15 iron. This proportion of arsenic is unusually high. Two objects of early date from Ur were received from the British Museum for micrographic examination, having a core of uncorroded metal. One proved to be a copper and the other a bronze, the structure showing that the former had been hammered and slightly reheated after casting, whilst the bronze was in the cast condition. Analyses :—

		Copper.	Tin.	Nickel.	Arsenic.	Lead.
Spear.	U 12239 BML III .	97·2	0·56	1·36	—	trace
Axe.	U 12098 BML XVI .	87·93	11·65	0·20	—	0·22

An arrow head from Anau, obtained from the Hermitage Museum at Leningrad, from its Director, through the good offices of the Foreign Office, was accidentally omitted from an earlier Report. A core of unoxidised metal was present, and the composition was :—

Copper, 96·85. Tin, 2·35. Iron, 1·25.

Nickel, arsenic and lead were absent. The object was found in the North Kurgan, but the layer in which it occurred was not indicated.

An analysis has been received from Philadelphia of the copper spearhead found by Mr. Woolley at Ur below the ' Flood ' level, and described as copper. The copper found was 99·69 per cent., with 0·16 arsenic, 0·01 iron, and 0·12 zinc, without a trace of nickel, tin, or silver. The zinc reported must be regarded as doubtful. The writer at one time found zinc in a number of specimens, which was at last traced to the presence of that metal in the glass vessels used for analysis.

The largest number of specimens examined has come from the excavations of the Oriental Institute of Chicago at Tell Asmar and Khafaje, sent by Dr. H. Frankfort, to whom the Committee is indebted for a grant of £20 to supplement that received from the Association. The bronze dagger which appears first on the list is of special interest, since it still held the remains of an iron blade, analysis showing that this iron is of terrestrial origin, and not, as in the case of other early iron objects, examined by the Committee, forged from a meteorite.

A portion of a spearhead from Nineveh, submitted by Mr. Mallowan, although completely oxidised, proved to be of pure copper, tin and nickel being completely absent, whilst the minute quantity of iron found (0·15 per cent.) may well have been derived from the soil.

A batch of specimens has been received recently from Dr. H. H. von der

Osten, Field Director of the excavations of the Oriental Institute of Chicago, at Alishar Höyük, in Anatolia. The analyses, so far as completed, are included in the table.

An Egyptian razor of the Fourth Dynasty was received from Sir Robert Mond. This thin razor, in very perfect preservation, had all the appearance of being of copper, but the analysis showed it to be a true bronze. Determinations of hardness showed that the edge had been hardened by severe hammering. Analysis :—

Copper, 88·5. Tin, 8·5. Iron, 1·8. Lead, 0·3. Nickel, 0·01.

A little slaggy matter was present.

Mention may be made of a few analyses published elsewhere. Dr. C. F. Elam has examined five objects from Mr. Woolley's finds at Ur (*J. Inst. Met.*, 1932, **48**, 97) and found two objects from the earliest levels to be true bronzes, whilst the later specimens contain either no tin, or a small and variable quantity. This is in accordance with our own observations. The nickel content recorded is mostly higher than that found by us, but is of the same order. Sir Harold Carpenter has examined an Egyptian axe head of early Dynastic age, this being a large object, weighing over three pounds. Analysis (*Nature*, 22 Oct., 1932) :—

Copper, 97·35. Nickel, 1·28. Arsenic, 0·49.
Lead, 0·17. Iron, 0·15. Manganese, 0·06.

The remainder being oxygen. Manganese is known to be associated with copper in Egyptian ores.

In the table which follows, the highly oxidised specimens have not been re-calculated, the reason being that the amount of earthy matter present is sometimes so large as to make it uncertain whether some of its components are to be attributed to the metal, whilst other specimens contain sulphur, derived from the ore, and present in the metal as sulphide. This sulphur has not been determined, but its presence is noted. In view of the high proportion of sulphur in many of the objects from Mohenjo-daro in the Fourth Report, specimens of the soil were obtained from Mr. Mackay, with the object of determining whether this sulphur was derived from the soil. Two samples were received, labelled ' Top of mound ' and ' Lowest levels ' respectively. Neither contained any sulphide, and the total quantity of sulphate in the lower layer was only 0·16 per cent., that in the upper layer being 1·92 per cent. The sulphur found in the specimens had, therefore, come from the ore. In the case of the Tell Asmar specimens, a core of uncorroded metal is sometimes present, in which sulphide may be detected under the microscope. It does not follow that the pyritic ores were deliberately smelted ; it may have been that the outcrop ores were more or less contaminated by sulphides.

Tell Asmar, Pre-Sargonid hoard.		Copper.	Tin.	Nickel.	Arsenic.	Lead.	Iron.
Bronze dagger .	1080	88·61	7·60	0·67	trace	0·94	0·46*
Vase	1051	85·51	0	0·02	0·05	0·36	—
Vase	1085	85·53	0	0·07	0·06	0·99	—
Tell Asmar, Akkadian.							
Lump or ingot .	764	95·01	0	0·62	0·25	0	— †
Implement . .	1317	52·90	0	0·13	0·67		†
Wire bangle . .	1239	93·96	0	0·11	0·11		
Arrow butt . .	559	87·48	0·74	0·32	1·57		

* Some oxide. † Much sulphur.

		Copper.	Tin.	Nickel.	Ar-senic.	Lead.	Iron.
Tell Asmar, Early Dynastic.							
Dagger blade . .	1329	90·82	2·63	0·33	0·15	0	0·15
Sickle blade . .	1131	88·11	0	0	2·23	0	0·40
Arrow butt . .	1048	61·50	0	0·36	0·37	0	— †
Arrow butt . .	1097	70·0	trace	0·39	0·86		
Rolled pin . .	1038	95·49	0	0·30	1·27	0	1·30
Rolled pin . .	986	87·81	0	0·90	2·08	0	1·04
Khafaje, Early Dynastic.							
Dagger blade .	1296	49·82	0	0·29	0·94	0·22	—
Rolled pin . .	465	39·70	0	0	0	trace	
Rolled pin . .	187	77·98	0	trace	0·22	0	
Lump . .	152	78·73	6·31	0·22	0·90	0	
Alishar Höyük, Anatolia, Copper age and transition period.							
	e—700	58·12	4·82	0·04	0·14	1·22	
	e—833	61·36	10·8	0·51	0·03	0	
	e—963	60·52	0·76	trace	0·11	0·40	

† Much sulphur.

MECHANICAL ABILITY.

Final Report of Committee appointed to inquire into the factors involved in Mechanical Ability (Dr. C. S. Myers, C.B.E., F.R.S., *Chairman*; Dr. G. H. Miles, *Secretary*; Prof. C. Burt, Dr. F. M. Earle, Dr. Ll. Wynn Jones, Prof. T. H. Pear).

Arising out of the work reported to the Association by the Committee on Vocational Tests in 1931, the present Committee arranged for a thorough revision and statistical examination of the results to be made. As an outcome of this work the need was apparent for a further examination of the routine manual factor which plays an important part in the process of repetitive manual operations.

I. Suitability of Measures.

Reliability.—The suitability of the measures upon which the conclusions of this report are based was carefully investigated. The reliability of the 'mechanical' tests (assembling and aptitude), as indicated by their intercorrelations, was in the neighbourhood of 0·6 to 0·7. That of the routine tests, based on the correlation of one test with a general repetition, varied from 0·52 to 0·91. The reliability of the 'intelligence' tests, based on the correlation between the sum of the odd sub-tests and that of the even, varied from 0·8 to 0·9.

The intercorrelation of each 'trial' with the other trials constituting the test was examined in the data on the routine tests obtained from the adult subjects. The figures indicated that the reliability of manual tests depended primarily on the number of repetitions (or 'trials') rather than upon the complexity and length of the 'trial' itself. About the same degree of 'reliability' could be expected from a given number of trials,

irrespective of the length of the operations that are being tested, and which constituted the ' trial.'

The figures also showed that, so far as the first five trials that constituted these tests were concerned, one ' trial ' was about as reliable as another. A similar result was observed during the much longer practice period, for it was found that the reliability of the ' test ' was much the same from one day to another, irrespective of the stage of the subjects' practice. Generally, the tests measured ' initial ' ability to about the same degree of accuracy as they predicted ability after practice.

Little difference in reliability was observed between the adults and elementary school subjects.

Incentives.—The correlation between the scores made at the various tests, and estimated ' incentive,' proved to be negligibly small. The results which we have now to examine can, therefore, hardly be explained on the basis of differences in incentive.

II. The Special Abilities (or Group-factors).

The Mechanical Factor.—Having secured reliable measures of ability, our next step was to determine the intercorrelations of all the tests in the case of each group of subjects tested (i.e. the ' adult ' group, and the several elementary school groups). It was at once evident from these correlations that the data tended to fall into three groups, viz.: (i) a ' mechanical ' group consisting of the mechanical aptitude tests and the mechanical assembling tests; (ii) a routine (or ' manual ') group composed of the routine assembling and stripping tests, and the simple manual tests, and (iii) a general intelligence group consisting of the tests and estimates of intelligence, and general school subjects.

The next step was to determine, by Spearman's method of tetrad-differences, how far these observed differences in the correlation coefficients are due to chance, or to differences in the degree of correlation which all of the other tests showed with the intelligence group. The application of this criterion indicated that although the general positive correlation running throughout the data could best be ascribed to a general factor common to all, there were also present group-factors, tending to produce a closer relationship between members of the same group than could be accounted for by this general factor.

To determine more precisely the location and range of the group-factors, the influence of the general factor was next statistically eliminated and the tetrad-difference criterion was then applied to the resulting specific correlations.

It is impossible to present here the numerous correlation tables examined in the course of the analysis. It must suffice to say that the following conclusions were clearly indicated:

(1) The specific intercorrelations of the ' mechanical ' group were best explicable by a single group-factor common to both the ' aptitude ' and the ' assembly ' tests. This seemed most reasonably identified with the mechanical factor (' *m* ') which was disclosed in the aptitude type of test in a previous research, and whose presence was thus confirmed in the present research, and shown, for the first time, to be present in suitable tests of the mechanical assembling type.

(2) The mechanical aptitude type (which, it will be remembered, involved no manual activity) were more highly saturated with the mechanical group-factor than were the assembling type, and therefore provide better measures of this *special* ability.

(3) It was definitely established that the group-factor in the 'mechanical' group was not the same as the group-factor in the routine 'manual' tests.

The Routine Manual Factor.—Statistical analysis of the manual tests along similar lines indicated that:

(1) The specific intercorrelations of the routine 'manual' assembling and stripping tests, and the simple manual tests, could be best explained by a single group-factor.

(2) This routine (or 'manual') factor was clearly distinguishable from the 'mechanical' factor seen in the mechanical aptitude and mechanical assembling tests.

(3) In general, the more complex assembling tests were more highly saturated with this factor than were the simpler manual tests.

(4) Where the tests were both very simple and very similar (such as screwing and unscrewing the turnbuckle), small additional factors common to the pair of tests concerned, and to these only, were observed.

The 'Abilities' in Assembling Work.—The independently measurable 'abilities' or 'group-factors' in assembling work were thus found to be (i) a mechanical factor, associated with the solution of a mechanical problem; (ii) a routine manual factor associated with the manual activity involved in this work; and (iii), to a less extent, general intelligence. As the work assumes a routine character the mechanical factor tends to disappear. There was little evidence of the routine factor in the mechanical assembling operations. In these the manual activity involved appears to function specifically, rather than as a group-factor.

The Organisation of Manual Activity.—The more complex forms of manual activity appear to depend on a broader and more important group-factor than earlier work on simpler manual tests would lead us to suppose. As the operations become simpler they depend less upon this common factor and more upon factors specific to the particular operation. The measurement of this group-factor, in relative independence of other factors, as provided by suitably constructed tests, would seem to be essential wherever vocational guidance or selection in the sphere of manual activity is in question.

III. The Mental Processes in Manual Activity.

The analysis divides into two parts. The first attempts to elucidate the cognitive processes involved in the solution of the mechanical problem which accompanies certain forms of manual activity such as that of the mechanical assembling operations. It thereby extends to manual activities the analysis of mechanical aptitude which the writer has already described in a former work. In the former analysis the problems were of a different kind and were uncomplicated by manual activity. The present extension of the analysis to include manipulative operations throws light on another large class of engineering occupations.

The analysis also includes an examination of the processes underlying the cognition of shape, and the relation of these to drawing and design. The results are therefore of vocational interest wherever the worker is called upon to deal with spatial material.

The second part of the analysis deals with those manual activities which involve no special mechanical problem and which we termed routine assembling operations. It attempts to unravel the cognitive processes associated with the manual factor which our objective measurements disclosed. It includes an account of the kind of knowledge that is acquired

by practice at manual operations, and an analysis into elementary processes of the mental activity essential to its acquisition.

The 'mechanical' factor and the 'routine manual' factor appear to enter into many occupations. It is hoped, therefore, that these analytical results when published[1] may find wide application in the field of vocational psychology, as also the methods of analysis which have been adopted.

TRAINING IN PSYCHOLOGY.

Report of Committee appointed to inquire into (a) the occupations for which a training in psychology is necessary or desirable, (b) the place psychology should occupy in the curricula for University degrees in Arts, Science, Medicine, Education, Economics and other subjects (Prof. F. C. Bartlett, F.R.S., *Chairman*; A. R. Knight, *Secretary*; Prof. F. Aveling, Dr. Wm. Brown, Prof. J. Drever, Prof. Beatrice Edgell, C. A. Mace, Prof. T. H. Pear, Dr. R. H. Thouless, Prof. C. W. Valentine, A. W. Wolters).

I. The Occupations for which a Training in Psychology is necessary or desirable.

1. A training in psychology is now recognised to be necessary for (i) teachers, who aim at forming mind and character, (ii) medical practitioners, who aim at curing mental as well as physical disorders, and (iii) industrialists, who aim at directing human energy in the most economical way; and educational, medical, and industrial psychology are three established branches of applied psychology. But a training in psychology is also helpful to any other person whose work lies in dealing effectively with human beings. It helps him not merely because it provides him with important and special knowledge of the human mind and of human behaviour, but also because it develops in him the habit of dealing with human relations and problems in an objective, scientific manner.

2. (i) *Medicine.*—Every physician should have received, in his medical course, a training in general psychology, and in the psychological treatment of mental disorder.

(ii) *Education.*—Intending teachers require a training in general psychology, and in the facts about mental growth and the formation of character, individual differences, abnormal and delinquent behaviour, the measurement of abilities, and the applications of psychology to methods of teaching.

(iii) *Theology.*—Clergymen require a training in general and abnormal psychology, in the psychological facts underlying religious and moral behaviour, and in the technique of effective pastoral work. Missionaries require, in addition, some knowledge of racial psychology and of the mental life of primitive peoples.

(iv) *Law.*—Both branches of the legal profession require, or at any rate benefit by, a training in general psychology, especially in its

[1] A detailed account of the analysis outlined in this report will be published in book form by the National Institute of Industrial Psychology.

relation to motivation, intelligence, mental defect, testimony, and the technique of appraising and dealing with people.

(v) *The Services.*—Officers in the Navy, Army, and Air Force require a training in general psychology, especially in its bearing on the selection and training of recruits, leadership, discipline, morale, and the mental disorders of warfare. Colonial administrators also require a training in general psychology and in the psychological problems raised by the government of native races.

(vi) *Industry and Commerce.*—Those aiming at executive or administrative posts in industry and commerce, or at salesmanship and advertising, need a training in general psychology and in the various branches of industrial and vocational psychology.

(vii) *Social Work.*—Those professionally or unprofessionally engaged in social or welfare work require a training in general psychology.

(viii) *Other occupations.*—A training in general psychology, especially in its dynamic aspects, is desirable for economists, historians, anthropologists, literary critics, biologists, and everyone else who aims at describing or explaining the thought and behaviour of men or animals. A course on the special senses is also required in scientific work where accuracy of observation depends on the accuracy of the response of human sense-organs. And there may well be other occupations for which some training in psychology is necessary or desirable.

II. The place Psychology should occupy in the Curricula for University Degrees in Arts, Science, Medicine, Education, Economics and other Subjects.

1. The present position of psychology in the universities of Great Britain lacks uniformity. In some universities there is a Professor of Psychology, while in others there is not even a specially appointed lecturer. In some there is a full, self-contained honours course in psychology, while in others psychology, if it is taught at all, forms merely a subordinate part of a course in some other subject. Again, in some universities a course in psychology qualifies for degrees both in Arts and in Science, while in others it qualifies for only one of these degrees or for neither. And these are not all the anomalies.

2. Psychology should occupy such a place in university curricula as will exhibit its distinction from philosophy and its status as an independent, positive science. The fundamental concepts used in psychology do indeed stand in need of philosophical analysis, as do those used in any other branch of empirical science. Moreover, since psychology deals with the thought and behaviour of men, its connection with philosophy and the other humanities is much closer than that of other sciences, like physics or chemistry. And for these reasons it is entitled to a prominent place in the Faculty of Arts in each university. Still, its position as one of the established biological sciences requires that it shall also be taught in every Faculty of Science. Its special cultural value should not be allowed to prejudice its scientific status. An independent, positive science that is of special importance to Arts students is still an independent, positive science.

3. (i) *Arts and Science.*—There should be pass courses and honours courses qualifying for degrees both in Arts and in Science.

(ii) *Medicine.*—Courses in psychology should be compulsory for first degrees in medicine.

(iii) *Education.*—Courses in psychology should be compulsory for degrees or diplomas in education.

(iv) *Theology.*—Courses in psychology should be available for theological students, and compulsory for those proposing to engage in pastoral work.

(v) *Law.*—Courses in psychology should be available for law students.

(vi) *Military Subjects, etc.*—If university courses are provided for prospective candidates for the fighting services, psychology should be made a compulsory subject in such courses.[1] Training in psychology should also be given to those aiming at the colonial administrative services.

(vii) *Economics, Commerce, etc.*—Courses in psychology should be provided for degrees in economics, commerce, industrial administration, etc.

(viii) *Social Science, etc.*—Courses in psychology should be compulsory for degrees or diplomas in social science, mental hygiene, welfare work, etc.

(ix) *General.*—Short courses on the art of study and effective thinking should be available for all university students, especially freshmen.

4. At present the Committee makes no recommendation as to the precise nature and length of these several courses, except in so far as the first part of this report indicates the different kinds of course which different occupations demand. But it does strongly recommend three things: (i) Every course should include experimental work. (ii) Even where some special application of psychology—as to medicine, or education, or industry—is the main subject of the course, this should always be presented against a sound background of general psychology. (iii) Every course should be given by a trained psychologist. At present psychology is often set before students (especially in Faculties of Medicine and Theology) by unqualified persons, with the result that the teaching and examinations are unsatisfactory and out-of-date.

TRANSPLANT EXPERIMENTS AT POTTERNE, WILTSHIRE.

Report of Committee on Transplant Experiments (Sir ARTHUR HILL, K.C.M.G., F.R.S., *Chairman*; Dr. W. B. TURRILL, *Secretary*; Prof. F. W. OLIVER, F.R.S.; Dr. E. J. SALISBURY; Prof. A. G. TANSLEY, F.R.S.).

THIS Committee was appointed by the British Association at the 1930 meeting and reappointed at the meetings in 1931 and 1932.

The second report on the progress of the experiments is being published in the *Journal of Ecology* for August 1933. A third report is in preparation.

The balance of £2 6*s.* 2*d.* of the British Association grant has been used to meet (in part) expenses represented by vouchers (receipts) which have been submitted. No further grant is asked for this year.

[1] Professor Pear and Dr. Thouless dissent from this on the ground that specific instruction in the application of psychology to problems of warfare should not be given in universities.

KLEINIA ARTICULATA.

Final Report of Committee appointed to investigate the effect of conditions on the growth, structure and metabolism of Kleinia articulata (Prof. D. THODAY, *Chairman*; Mr. N. WOODHEAD, *Secretary*; Dr. F. F. BLACKMAN, F.R.S.).

THE starvation experiments referred to in the last report showed that malic acid is broken down in the later stages, and associated with this is a marked increase in the pH of the sap. When protoplasmic breakdown occurs in the pith, the pH of the escaping sap reaches about 8.

Observations on wound-healing have been continued and extended to *Kleinia neriifolia* and other species. The distribution of solutes in these other species has also been examined.

An experiment, lasting five weeks, was carried out in the three chambers previously mentioned, each chamber illuminated by a 500-watt Osram lamp with white dispersive reflector and running-water screen. In each, 24 cuttings, previously sprouted in the dark, were exposed respectively to daily periods of illumination of 8 hours, 12 hours and 15 hours. The temperature in the chambers during illumination was about 18–20° C., and fell in the intervals to about 16–17° C. In the 15-hours chamber many of the sprouts rapidly withered. In the 12-hours chamber most of the shoots showed a more or less marked tendency to plagiotropism, which was only shown by a few in the 8-hours chamber. The average elongation was greatest with the shortest daily illumination, least with the longest. Further experiments are contemplated for further analysis of these effects.

The stock of plants was depleted by this experiment, and attention has since been concentrated on replenishing it. The work will be continued, but the Committee does not apply for reappointment.

The following papers have appeared during the year:

H. EVANS: 'The Pentosan Content of *Kleinia articulata*,' *Biochemical Journal*, xxvi, 1095–1100 (1932).

D. THODAY and H. EVANS: 'The Distribution of Soluble Calcium and Phosphate in the Tissues of *Kleinia articulata* and some other Plants,' *Ann. Bot.*, xlvi, 781–806 (1932).

D. THODAY and H. EVANS: 'The Distribution of some Solutes in the Tissues of *Kleinia articulata*,' *Ann. Bot.*, xlvii, 1–20 (1933).

GENERAL SCIENCE IN SCHOOLS.

Final Report of Committee on the Teaching of General Science in Schools, with Special Reference to the Teaching of Biology (Dr. LILIAN J. CLARKE, *Chairman*; Mr. G. W. OLIVE, *Secretary*; Mr. C. E. BROWNE; Major A. G. CHURCH, D.S.O.; Mr. G. D. DUNKERLEY; Mr. S. R. HUMBY; Sir PERCY NUNN; Mr. E. R. B. REYNOLDS; Dr. E. W. SHANN; Dr. E. M. THOMAS; Mr. A. H. WHIPPLE; Mrs. GORDON WILSON; Miss VON WYSS).

CONTENTS.

I. INTRODUCTION.

THE committee undertook to ascertain as far as possible the position occupied by General Science with special reference to the inclusion of Biology in the curriculum of secondary schools of England and Wales. The term General Science has frequently been taken to mean physics and chemistry alone. It is therefore to be understood that the term when used in this report means a course or syllabus which includes at least a study of living things, both plant and animal, together with physics and chemistry. In order to give the inquiry its maximum value, the co-operation of heads of secondary schools and science teachers was invited, and this assistance was fully and freely given. Teachers were obviously interested, and a large number of questionnaires were returned, completed in detail and supplemented by explanatory notes.

At the outset, members of the committee were conversant, broadly speaking, with the position occupied by General Science in the schools. They were aware of the work undertaken by various bodies and pioneers in the past, and of the investigations already made. Their first step was to prepare a historical review of the growth of opinion in favour of Biology as a part of the general science work of a school. Their next step was to obtain as complete and comprehensive information as possible on—

(1) The extent to which General Science was already adopted in the schools;

(2) The attitude of heads of schools and science teachers towards the value of General Science under the present organisation of schools.

This information they sought largely by means of questionnaires, circulated to schools throughout the country. In this connection, certain selected schools were invited to supply information on special features of their out-of-school activities, as ancillary to the work carried on in school.

As examinations play a large part in determining the type of science work in schools, and exercise a restricting influence on a school's freedom in the choice of subjects or in the scope of a subject, the committee have considered the problem of school examinations in relation to the adoption of General Science as a school subject.

Out-of-school activities play an important part in science teaching. It was essential, therefore, to obtain information on this point also, and again

heads of schools and science teachers gave every assistance. The mass of information actually received was large as well as pertinent, and the report can do no more than present this in outline.

At the end of the report will be found a summary as well as a statement of the conclusions at which the committee has arrived.

II. Historical Review.

The principle that School Science should include more than elementary physics and chemistry can be traced back many years. It was in fact present in the minds of those who first advocated the study of science in schools. Huxley in 1854, when referring to the educational value of Natural History sciences, said : ' Biology needs no apologist when she demands a place, and a prominent place, in any scheme of education worthy of the name. Leave out the Physiological sciences from your curriculum, and you launch the student into the world, undisciplined in that science whose subject matter would best develop his powers of observation ; ignorant of facts of the deepest importance for his own and others' welfare ; blind to the richest sources of beauty in God's creation ; and unprovided with that belief in a living law, and an order manifesting itself in and through endless change and variety, which might serve to check and moderate that phase of despair through which, if he take an earnest interest in social problems, he will assuredly sooner or later pass.'

The Royal Commission in 1860 recommended that all boys should receive instruction in some branch of natural science during at least part of their school life, that there should be two branches : one consisting of chemistry and physics, and the other of physiology and natural history, animal and plant.

At the Nottingham Meeting of the British Association, 1866, a committee was appointed, which included Professors Huxley and Tyndall and Canon Wilson, ' To consider the best means of promoting Scientific Education in schools.' Ample reference to their report, issued in 1867, was made in the *Report on Science Teaching in Secondary Schools*, published in 1917, but it may be noted here that the list of science studies recommended included : simple facts of astronomy, of geology, and of elementary physiology, experimental physics, elementary chemistry, and botany.

Canon Wilson, in his *Essays on a Liberal Education*, published in 1867, describes the methods adopted when introducing science teaching in Rugby School ; he explains that it was lack of equipment and of teachers that limited the work actually adopted to Botany and Physics, these two being claimed as the standard subjects for the scientific teaching in schools. Chemistry was not then considered possible owing to difficulties in obtaining suitable apparatus and equipment.

In 1884 Prof. H. L. Armstrong, when speaking at the International Conference on Education in London, said : ' In my opinion no single branch of natural science should be selected to be taught as part of the ordinary school course, but the instruction should comprise the elements of what I have already spoken of as the science of daily life, and should include astronomy, botany, chemistry, geology, physics, physiology and zoology. . . . The order in which these subjects should be introduced is a matter of discussion ; personally I should prefer to begin with botany, and introduce as soon as possible the various branches of science in no particular order but that best suited to the understanding of the various objects and phenomena to which for the time being the teaching had reference.'

Encouraged by grants made on results of examinations by the Science and Art Department, and influenced by the establishment of scholarships in Natural Sciences at Oxford and Cambridge, and by the inclusion of science subjects in the requirements of London Matriculation examinations, most schools had by 1890 included science teaching of some kind in their curriculum. The teaching of botany, however, did not long survive in boys' schools, by the end of the century it was mainly confined to girls' schools. In 1903 a British Association Committee on 'The Teaching of Botany in Schools' issued a report on methods of teaching the subject. The report drew attention to the need for substituting an experimental study of living plants for the excessive study of classification and morphology which then obtained in the majority of botanical classes; emphasis was laid on the need for the pupils to work for themselves, to be the inquirers, and the recorders of actual experiences instead of being the recipients of didactic lessons by teachers. It was further asserted that 'In Botanical and Zoological teaching, more than in any other scientific courses, it is easy to adopt improved methods.'

Instead of developing on broad lines advocated in the early years, science teaching in boys' schools became almost wholly concerned with physics and chemistry, and for the most part with only very restricted parts of those subjects. The influence exerted by the highly specialised university requirements for a science degree contributed in no small way to consolidate this tendency, for the majority of science degrees were awarded to persons without the most elementary knowledge of biology.

The withdrawal of botany and zoology as compulsory subjects for the Intermediate Science Examination of London University in 1898 has been, in the opinion of many teachers, a contributory cause for the decline in interest in biology in schools, and a cause of the deficiency of candidates for that subject at the University. All London graduates in science had, up to that time, at least some knowledge of biological principles and facts.

The report of the British Association Committee on 'Science Teaching in Secondary Schools,' published in 1917, gives a survey of the position of science teaching at that date, and includes important memoranda on methods of teaching science, on the value of experimental work, on inspection and examination, and on school organisation so far as it affects the adequate treatment of the subject.

About the same time the Civil Service Commission attempted to bring the teaching of science in schools more into relation with the facts of daily life by demanding for certain examinations a much broader type of science study than was usual in schools. Similarly the Science Masters' Association made a vigorous effort to obtain recognition for General Science in the School Certificate Examinations. In response to this the Oxford and Cambridge Joint Board and the Delegates of the Oxford Local Examination provided a General Science paper alternative to those of the special subjects of physics and chemistry.

In 1917 the extension of sixth-form work in grant-aided secondary schools was encouraged by the institution of advanced courses by the Board of Education. The grant of £400 made in connection with each such course made it possible to free a teacher for the instruction of a comparatively small number of pupils in the sixth form, and to give help in the equipment of laboratories and libraries. In the first year, 1917–18, 127 courses were recognised, 82 of which were courses in Mathematics and Science. In 1924-25 there were 469 courses, 235 being courses in Mathematics and Science. There can be little doubt that the science work

in the schools containing Advanced Courses in Science Subjects developed considerably under their influence. It might have been expected that the existence of specialised courses in the top forms would have left the science staff free to devise a General Science course covering the years between the years 12 and 16, based in the main on the needs of that large majority of the pupils who leave school on reaching the latter age. Unfortunately this does not appear to have been the case; on the contrary, there has been a tendency to frame the science course with a view to covering as much ground as possible in the subjects of the Advanced Course, and specialisation has spread down the school.

A report was published by the Prime Minister's Committee on 'Natural Science in Education' in 1918 (reprinted in 1927). It stressed the need to broaden the basis of science work in secondary schools, saying:

'Some knowledge of the facts of the life of plants and animals should form a regular part of the teaching in every secondary school. . . . The main facts as to the relation of plants and animals to their surroundings, and the changes in the material and in the energy involved in life and growth should form part of a well-balanced school course.'

The same report deals in some detail with various conditions affecting the teaching of science, such as the influence of examinations, the supply, qualifications and training of teachers, university requirements and laboratory accommodation, and says:

'The want of teachers with wider scientific qualifications is at present the real difficulty in the introduction of biology into school work.'

In a summary of the principal conclusions of this committee the following are worth quoting, as they refer to the science course recommended for pupils of ages 12 to 16:

'The science work for pupils under 16 should be planned as a self-contained course, and should include besides physics and chemistry some study of plant and animal life. . . . More attention should be directed to those aspects of the sciences which bear directly on the objects and experiences of everyday life.'

By 1920 there was a rapidly growing opinion that biology is a necessary element in all school science, and that neither botany nor zoology as separate subjects could take its place. In most girls' schools botany had long been a recognised subject of the curriculum. Only in comparatively few boys' schools had biology been given any serious consideration. Natural history of a very elementary type sometimes formed the early stages of a science course, but it was, more often than not, relegated to voluntary work out of school hours as part of the work of the Natural History Society.

In 1924 the committee of the Science Masters' Association again attacked the problem in their publication *General Science*. In order that there should be no misunderstanding as to the meaning of the title, the authors expressly 'consider that, in any well-balanced course, Biology with Human Physiology and Hygiene is entitled to about one-quarter' of the total time given to the science course as a whole. The pamphlet has helped to focus attention upon the need for reform in school science, it has encouraged teachers fortunately placed as regards freedom of action to draw up their own courses, to make trial of them and to give others the benefits of their experiences. The revised edition, published in 1932, has two specimen syllabuses, and suggestions for practical work, especially with respect to the biological aspect of the course. In *General Science* it is especially claimed that 'the whole essence of General Science lies not in the syllabus, but in the interpretation of it. . . . It must not be merely bits of specialist science. . . . General Science aims at unity,' to 'be conceived as something

whole and undivided,' and 'General Science will not be successful unless it is treated as a whole.'

In 1925 the Board of Education issued a report of an inquiry carried out by their Inspectorate on the conditions affecting science teaching in a number of large urban secondary boys' schools. It pointed out that the recommendations of the Prime Minister's Committee of 1918, on the desirability of some elementary teaching of biology as a part of the normal curriculum of boys' schools, had produced, so far, practically no effect on the science syllabuses in those schools.

In 1926 the Hadow Report on the 'Education of the Adolescent' suggested 'That most schemes for courses in elementary science in modern schools, central schools, and in senior classes of elementary schools might be grouped round a simple syllabus consisting of:

'(*a*) The chemical and physical properties of air, water, and some of the commoner elements and their compounds, and elements of meteorology, and astronomy, based on simple observations, and the extraction of metals.

'(*b*) A carefully graduated course of instruction in elementary physics and simple mechanics, abundantly illustrated by means of easy experiments in light, heat, sound, and the various methods of production and application of electricity.

'(*c*) A broad outline of the fundamental principles of biology describing the properties of living matter, including food, the processes of reproduction and respiration, methods of assimilation in plants, the action of bacterial organisms and the like.

'(*d*) Instruction in elementary physiology and hygiene based on lessons in biology.'

It contained, on page 223, the following recommendations:

'(1) As a general rule, in country schools the science syllabus both for boys and girls might be largely based on biological interests, the study of elementary physics and chemistry being subsidiary but arranged so as to supply the indispensable foundation for a course in elementary biology with special reference to its bearing on horticulture and agriculture.

'(2) Science courses for girls in modern schools and in senior classes should in their later stages frequently have a biological trend. . . . The work should not be confined to botany, as the study of simple forms of animal life can, under a wise and skilful teacher, be made an admirable means of widening and disciplining the pupil's sympathies, and giving her broad hygienic ideals and a knowledge of nature which may increase her happiness and efficiency as a human being.

'(3) Instruction in elementary physiology and hygiene developing out of the lessons in elementary biology should be given to all boys and girls in Modern Schools and Senior Classes. Such instruction should be largely the practical outline of a study of elementary biology, treated, not as a series of classifications but as the study of the development of form and function in suitable types of plant and animal life, leading up to a study of how the human body is built up and how it works. Such instruction in biology and elementary physiology, if properly carried out, might well provide the basis for a right attitude to many social problems.'

In 1928 a British Association Committee of Zoologists published a report on ' Animal Biology in the School Curriculum.' In this report the committee regarded the principle that biological teaching should have some place in the education of all children as generally admitted, and after emphasising the unity of this teaching in that it must take in the whole range of life, plant and animal kingdom alike, they dealt mainly with the amount and scope of studies to be recommended. They made suggestions for the actual building up of a scheme of work, and presented in outline a syllabus of biology for pupils from 11 to 16 years of age.

In 1929 the British Association Committee on Educational Training for Overseas Life again urged that a broader view should be taken of the function of school science as a preparation for life and service. They viewed with satisfaction the movement to introduce biological studies into the curriculum. Such studies dealing with the living environment of the child, they claimed, would introduce naturally and purposefully most of the biological work possible in many schools as well as much of the physical science necessary.

' In Rural Studies, schools would possess an educational instrument of wide adaptability, affording intellectual material of the highest kind. . . . The contact with life which rural studies bring gives purpose and reality to school work generally ; they create interest and provide a rational basis for all branches of scientific inquiry. . . . These studies provide opportunities for a simple approach to the physiological processes of life, and, when correlated with the teaching of geography and history, constitute a basis of instruction of far-reaching importance.'

The report draws attention to the chief causes of the slowness of the schools to extend their biological work, a course so strongly urged by educationists and so clearly in accord with the needs of the time.

In 1929 the British Association Committee on Science in School Certificate Examinations showed, in their report, that a detailed analysis of examination statistics proved that ' General Science occupies a low place in comparison (with specialist subjects) and biological subjects other than botany are deplorably neglected.' This report includes some valuable and suggestive syllabuses both for General Science and for Biology.

In 1929 a report on the condition of science teaching in Oxfordshire, compiled by a committee of the Oxfordshire Branch of the Assistant Masters' Association, emphasised the need for the inclusion of biology in the science work of the schools.

In 1929 the Friends' Guild of Teachers published a report based on answers to a questionnaire sent to the Friends' schools, to a number of other well-known schools, and to a number of specialist teachers. In answer to the questions, ' What Life Sciences ought to be included in the curriculum for pupils aged 12 to 18, and on what grounds can their inclusion be adequately justified,' the following expression of view summarises the general opinion :

' There is but one " Life Science "—Biology, of which Nature-study, Hygiene, Botany, Physiology, Zoology are specialist sub-divisions. Too generally at present the instruction of Life Science in schools provides little more than some knowledge of Nature Study, Hygiene and Botany, and a very strong case can be made out for instruction in the general principles of Biology even as early as the first stage—10 to 12 years of age.'

In February 1932, a committee of the Economic Advisory Council, presided over by the late Viscount Chelmsford, reported on the ' Education and Supply of Biologists.' The report, besides making recommendations on the education of specialists for work at home and overseas, urges the

inclusion of biology in schools ' as a cultural subject apart from its value for medicine and for the professional biological services. Biology should be brought to the notice of every boy, and none should leave school without some knowledge of it,' and further, ' the introduction of biology into the schools as a general cultural subject is essential in that the interests of the ordinary boy requires consideration as much as those of the scholarship candidate.'

A memorandum on ' Science in Senior Schools ' (Board of Education Pamphlet No. 89, 1932) reports that 214 out of 584 senior schools pay no attention to Biological sciences. Out of 599 men science teachers, only 38 have qualifications in Biology, while 198 women teachers had 111 qualifications in Physics, 129 in Chemistry, 117 in Botany, and 51 in Zoology. The memorandum recommends three periods a week as the minimum for science in senior schools. It makes suggestions for teaching various aspects of physics, chemistry and biology, urges constant cross-references between all parts of the science course, and gives lists of apparatus and equipment considered necessary.

A National Conference on ' The Place of Biology in Education ' was held in London, November 1932, under the auspices of the British Social Hygiene Council. The conference lasted three days and dealt with the following aspects of the subject :

(1) The National and Imperial Need for a Biological Outlook.

(2) The Place of Biology in Public Education, including :

- (*a*) Biology as an Integral part of Science ;
- (*b*) How Local Education Authorities can further the Teaching of Biology.
- (*c*) The Teacher's contribution to Biology.

(3) Biology in the Training Colleges.

(4) Biology in National Life.

(5) Biology in the Elementary School.

(6) Biology in the Public, Secondary, and Preparatory Schools.

A discussion followed on the schemes for teaching Biology submitted for consideration by Prof. Julian Huxley, Prof. W. Cullis, and Prof. Sir J. A. Thomson.

A report on the School Certificate Examination, prepared by a panel of investigators appointed by the Secondary Schools Examinations Council to inquire into the working of the examination in question, was published by the Board of Education in 1932.

III. Analysis of the Results of the Questionnaire.

The questionnaire sent out by the committee asked for information on the following topics :

(1) The present position of science in the schools and science subjects taught.

(2) The position of Biology in the schools.

(3) The position of General Science, taking that term to include chemistry, physics and biology, at least.

(4) If Biology and General Science are not commonly taught, what are the reasons for their exclusion ?

(5) Where General Science is taught, is it found to be advantageous o disadvantageous for the specialised work later in the school course ?

1. *The present position of science in schools and science subjects taught.*

In England and Wales there were (March 31, 1931) 1,367 State-aided and 362 non-aided secondary schools. The questionnaire was sent to the majority of these schools, and replies were received from 98 boys' schools, 198 girls' schools, and 62 mixed schools. Table I shows to what extent the various subjects were studied in these 358 schools.

TABLE I.

	Boys'.	Girls'.	Mixed.
Percentage of schools taking Chemistry.	97	83	92
,, ,, ,, ,, Physics .	97	72	87
,, ,, ,, ,, General Science .	56	69	50
,, ,, ,, ,, Biology .	25	41	32
,, ,, ,, ,, Botany .	22	84	52
,, ,, ,, ,, Zoology .	16	27	21

It is clear from this table that chemistry and physics dominate the science work in boys' schools and in mixed schools, but the position in girls' schools is not at first obvious. To clarify it, Table II shows the percentage of pupils taking the various science subjects.

TABLE II.

	Boys'.	Girls'.	Mixed.
Number of schools	98	198	62
Average percentage of pupils taking Chemistry .	50	26	51
,, ,, ,, ,, ,, Physics .	55	21	50
,, ,, ,, ,, ,, General Science .	37	40	42
,, ,, ,, ,, ,, Biology .	21	26	28
,, ,, ,, ,, ,, Botany .	4	31	24
,, ,, ,, ,, ,, Zoology .	4	4	3

This table, taken in conjunction with Table I, makes it clear that botany is still a popular science in girls' schools, but that General Science appears to be holding an important position. It must be noted that the above figures are liable to be misleading as many schools have courses in General Science for the younger pupils, but do not carry the subject on to the school certificate stage. Of 137 girls' schools taking General Science, we are informed that only 35 take the subject in school certificate, whereas almost all the 167 taking botany and two-thirds of those taking chemistry present it for examination. It is fair to conclude that in boys' and mixed schools chemistry and physics dominate the science work, and in girls' schools there is a wider field. General Science is usually taken as an introduction for pupils of ages 11 to 13, and further, it is clear, from a second inquiry that was made, that in many schools ' General Science ' is taken to mean chemistry and physics only. None the less, General Science in the broader sense is evidently becoming more popular than it was a few years ago.

It may be profitable to add a note here about Nature Study. This may be conveniently done in the form of Table III.

TABLE III.

	Boys'.	Girls'.	Mixed.
Number of schools	98	198	62
Percentage of schools taking Nature Study	26	42	44
Percentage of pupils of these schools taking Nature Study	14	19	25
Percentage of schools taking Nature Study and not Biology	12	20	23
Percentage of schools taking Nature Study and Biology	14	22	21
Percentage of schools taking Biology but not Nature Study	29	30	18
Percentage of pupils taking Biology in these schools	13	21	24

The replies to the questionnaire show that Nature Study is generally taken for the first year or two of the pupil's school life only ; in very few schools is it taken beyond the age of 12.

2. *The position of Biology in Schools.*

TABLE IV.

	Boys'.	Girls'.	Mixed.
Number of schools	98	198	62
Percentage of schools taking Biology	25	41	32
,, ,, pupils taking Biology in these	21	26	28
,, ,, schools taking Biology in school certificate	11	16	19

The last line of figures may be taken as a fair measure of the seriousness with which biology is pursued in schools.

3. *The position of General Science.*

It is very difficult to obtain figures which give a reliable account of the position. All the following subjects are studied by various schools as part of their general science courses : chemistry, physics, botany, physiology, physical geography, astronomy, biology, zoology, geology, soil science, nature study, domestic science, hygiene, and meteorology. In some schools the course is evidently an introductory one leading on to a more detailed survey of two or more subjects, in others it is a general course for senior pupils who are on the classical or modern languages side. In some schools the course is experimental ; in others it consists of reading and lectures only. It will be clear that figures showing the number which take General Science will be misleading, and for that reason the figures for General Science in Tables I and II must be accepted with caution. It is possible, however, to give a few figures whose meaning is clear.

TABLE V.

	Boys'.	Girls'.	Mixed.
Number of schools	98	198	62
Percentage of these taking General Science	56	69	50
,, ,, pupils taking General Science in these	37	40	42
,, ,, schools taking General Science in school certificate form	22	18	15

(The figures in the last line may be a little too high, but are certainly not a little too low.)

4. *Reasons why Biology and General Science are not commonly taught.*

Tables IV and V show that at present neither General Science, including biology, nor Biology is taught as much as other scientific subjects. The main reasons given in questionnaire answers for the absence of biological teaching are tabulated :

Reason A.—Omission due to the requirements of some School Certificate Examination.

Reason B.—Lack of suitable teachers.

Reason C.—Lack of suitable accommodation.

TABLE VI.

	Boys'.	Girls'.	Mixed.
Number of schools	98	198	62
Percentage of these giving reasons why Biology is not taught	53	36	35
Of schools giving reasons why Biology is not taught:			
Percentage, Reason A	45	50	41
Percentage, Reason B	47	33·3	45
Percentage, Reason C	43	39	41

Some schools give more than one reason.

It should be noted that the above reasons were those suggested in the question paper, and they are the most common reasons given. They may be taken as the effective reasons for the exclusion of biology at present, but, from their nature, they could be overcome if the desire for biology were sufficiently urgent. Other reasons which occur fairly often are 'Crowded curriculum,' 'Insufficient time,' 'Lack of demand generally,' 'Superior claims of physics and chemistry,' 'Unsuitable subject for young pupils.' A few schools state that they do not consider biological subjects to have a greater claim to inclusion than sciences already taken. Generally it may be said that schools are alive to the value of biology as an educational subject, but they do not see their way to introduce it owing to their overcrowded time-table or to difficulties connected with staffing or accommodation. They also doubt whether gain in breadth of teaching is a real compensation for loss in depth.

Considering one of the main reasons in more detail—difficulties connected with the school certificate examination—it is evident that a large number of schools find this a very serious factor in their decision to exclude biology. General Science including biology is not accepted for matriculation in most universities, whereas chemistry and physics are. If a pupil can take chemistry and physics as two subjects in the school certificate examination, both acceptable for matriculation, it is probable that schools will take the two subjects and exclude biology. (It may also be pointed out that most professional bodies do not accept General Science as a qualifying subject for the preliminary examinations.)

Further, with regard to the taking of biology as a separate subject in the school certificate examination, certain difficulties are raised. In town schools it is said to be more difficult to obtain material for the teaching of zoology than for that of botany, and that in any event, botany is an easier subject for class teaching than zoology. With the same time available, teachers say (1) it is easier for pupils to pass examinations in botany than in biology ; (2) botany is cheaper than biology, both in materials and apparatus ; (3) where the number of science pupils is small, it is very expensive to take up a third science owing to increase of staff ; (4) the classes would have to be smaller than is profitable.

Many heads of schools are not convinced that biology has any advantages over botany or other sciences as an examination or as an educational subject, and they are leaving matters in their present position until they can be sure that a change is desirable.

5. *General Science in relation to later specialised work.*

The fifth point set out in the questionnaire was the advantage or otherwise of General Science as a foundation for the specialised work later in the school course. In considering the answers given, it should be borne in mind that the term ' General Science ' has different meanings for different schools. The following shows the opinions of those schools which take General Science and which give their views :

TABLE VII.

	Boys'.	Girls'.	Mixed.
Number of schools	98	198	62
Percentage of these taking General Science	56	69	47
Percentage of schools stating General Science advantageous for later work	20	44	20
Percentage of schools stating General Science disadvantageous for later work	3	3	5
Percentage of schools taking General Science in School Certificate forms	22	18	15

On the face of this evidence it would appear that the opinions expressed were overwhelmingly in favour of General Science but for the lack of certainty as to what precisely is meant by ' General Science,' and what by specialised work later in the course. An examination of the replies to the questionnaire shows that about seventy schools consider two sciences constitute a General Science course, and of these two, biology is very seldom one. Further, by ' specialised work later in the school course,' some schools mean Higher School Certificate work and others mean School Certificate work. It is clear that, in the first case, the General Science course will mean a course extending over three or four years, whereas in the second it may mean one or two years' work with younger pupils.

Probably the best way to give an accurate impression of the views stated is to quote from them, dealing first with those schools which have a General Science course of three or four years.

(1) General Science is taught only to non-science specialists. I should strongly disapprove of science specialists going through a course of General Science.

(2) From an educational point of view, entirely advantageous. From the point of view of the necessity of passing School Certificate it is still advantageous, though the time spent on non-examination subjects is sometimes grudged by boys. It is greatly to be desired that a School Certificate paper in General Science acceptable for matriculation should be provided ; a paper consisting of so many chemical, physical and biological questions in water-tight compartments does not meet the case. (The point about a General Science paper acceptable for matriculation is made by several other schools.)

(3) It is certainly true that a General Science course with its wider scope is not advantageous to the specialised work later on, as there is a limited amount of time available for the study of science, and what is gained in breadth is lost in depth. Nevertheless I am sure that a General Science course is desirable.

(4) As science scholarships are at present awarded it is hardly possible to obtain scholarships unless specialisation in physics and chemistry begins at fourteen, and at this age only the modern forms go on with General Science.

(5) It would be an advantage to Higher School Certificate work if General Science were taken up to School Certificate standard; for examination requirements we find it easier to take a special subject.

(6) We consider that a General Science course is too disconnected and not a scientific training, and therefore not a good foundation for later work.

(7) General Science course advantageous on the whole, but only in so far as it is amplified by more special work for two years below School Certificate standard if advanced work is aimed at after matriculation.

These opinions, typical of many more, would seem to indicate that General Science is approved educationally but it is not the best possible preparation for the present matriculation or scholarship work. Dealing now with those schools whose General Science course comprises one to three years in the early part of the school life, it may be said at once that the general consensus of opinion is favourable. Very many schools mention that a knowledge of the elements of one science is essential to a proper understanding of the more advanced work in another science. Very few schools object to General Science in these early years, and of those that do, a number are largely concerned with the need for more specialised knowledge necessary for examination in separate subjects later in the school course.

Generally, then, it may be stated that most schools which have taken General Science find the subject of value educationally, and based most of their objections to it on the needs of matriculation and scholarship work.

(In this analysis the opinions stated are those given to the questionnaire except where it was necessary to gather up, in a comprehensive sentence, the views previously stated.)

IV. Examinations.

At present the regulations and schedules of the various School Certificate Examination Boards decide to a great extent the content of science teaching in schools. In some schools these schedules decide also the form in which the instruction is given, and control much of the laboratory work.

A number of examining bodies include General Science as a subject for the First School Examination, but three of them at present consider General Science to be a course which includes only chemistry and physics.

Several universities do not at present accept General Science as a qualifying subject for University matriculation.

Much effort has been expended in late years in attempts to standardise more accurately the marking and grading of examinations. There is perhaps one danger here to which attention may be drawn. Certain types of questions are easy to set and easy to mark with precision. Unfortunately, facility in answering them can be acquired without any real knowledge of science or understanding of scientific method. This sort of question reacts injuriously on the teaching of science. The school teachers, who in recent years have been invited in increasing numbers to assist as examiners and critics of the papers, can help materially by combating questions of this type. The committee would welcome an extension of the system by which teachers are utilised as examiners or moderators.

In 1932 a panel of investigators appointed by the Secondary Schools Examination Council issued a report on the School Certificate Examinations. The report was drawn up after an extensive investigation, and the panel was able, from its constitution, to obtain material which would be available to no other body. Included in the report of the panel of investigators is a recommendation that all candidates in science should be obliged to take a paper in 'Elementary Science' (by which is meant a course similar to

what is called 'General Science' in this report). While this committee is of opinion that the recommendation if adopted would lead to an improvement in the study of biological sciences, yet it would prefer some alteration in the syllabuses set for examination purposes which would ensure that all candidates sitting for the science papers should have passed through an adequate course of General Science as defined previously.

[1] The report suggests that optional papers in chemistry, physics and biology should be retained as additional subjects, and candidates should be allowed to take one or more of these. Candidates who, in good faith, take all these additional papers might be exempted from the Elementary Science paper.

The present system of examinations encourages a narrow specialisation which is unsound educationally. A school may find that candidates for, say, physics only have a greater chance of examination success under the present arrangement than they would if they took General Science. 'It will be clear that such an attitude towards science teaching is due to making the School Certificate Examination an end in itself rather than a means to test the results of a course of general education before the pupil begins such a course of specialisation as is appropriate for secondary schools." (*Circular* 849, B. of E.) 'It is a cardinal principle that the examination should follow the curriculum and not determine it' (*loc. cit.*). A course which deliberately sacrifices the best education of the pupil to the desire of passing an examination is hard to defend.

A further recommendation of the panel is that which advocates 'Easy papers and a high standard of marking.'

The plain fact is that it is extremely difficult to test a pupil's appreciation of science, and possibly no written test can be adequate. The one person who should be able to say whether the pupil is well grounded in science is the teacher. If the teacher is personally known to the examiner, the latter may be able to judge of the value of his opinion. Actual contact between examiner and teacher is very desirable. One examining body sends an examiner to each school for the practical examinations in science, and it is clear that the system has great advantages. In a few years the examining body would have a shrewd idea of the value of each school and of each science teacher, whereby the work of the pupils could be more accurately known and assessed. The chief obstacle in the way of adopting the system generally is the size of some of the School Certificate Examinations. (Over 17,000 candidates sat for the School Certificate Examination of one authority in 1931.)

The committee feel bound to state, however, that they see no ultimate value in this tendency to standardisation of methods, materials and results. Assuming that the one perfect School Certificate Examination were uniformly adopted, the committee would not be satisfied. It is a commonplace to say that much of the work of a school cannot be examined, and it is not too much to say that many of the most valuable parts of a pupil's make-up cannot be tested by any written work. This applies with great force to a pupil's work in science. The efficient school will continue to turn out the good pupils and the inefficient school the bad ones however perfectly the School Certificate Examination be devised, and the committee feel that efforts to increase the efficiency of schools are of more ultimate value than efforts to improve the efficiency of examinations. If it is asked to state what efforts it has in mind, the committee would suggest more frequent inspection, more pedagogic research, a more rigorous selection of candidates for the teaching profession, more efficient training of teachers.

[1] This committee would have preferred the report to have included options so that pupils could take papers in Botany, Zoology or Biology as additional subjects.

School Certificate Biology.	O. & C.J.B.	O.L.	C.L.	London.	Durham.	C. Welsh.	N.U.J.B.	Bristol.
Papers (in hours where stated)	I, II	1½, 1½	I, II	3	3, P		3	3
Demonstration of dissection = d; lens = l; microscope = m	l, m	l	d, l, m	d, l	l	d, l, m	l	d, l
Knowledge of Elementary Physics and Chemistry	+	esp.	+	+	+	+	+	+
Differences between animals and plants	+	+	Not separately specified	+		+		
Food materials; nature and assimilation of	+	+		+			+	
Respiration; energy relation	+	+		+	+	+	+	+
Reproduction; sexual and asexual	+	+				+	+	
Reaction to stimuli	+	+		+	+	+	+	+
Cellular structure		+						
Soil Science = s; C. & N. Cycles = c	c			s, c	s			
Structure and functions of flowering plant	+	+	+	+	+	+	+	+
Herbaceous and arborescent types	+	+	esp.	esp.	+		esp.	+
Floral structure; Buttercup = B; Pea = P; several = ∝	∝	B, P	B, P		∝	∝	∝	∝
Fruits and seeds; dispersal = d; germination = g	d, g	d, g	d, g	d, g	d	d	d, g	d, g
Tubers, corms and bulbs	+		+	+	+		+	
Algæ; Chlamydomonas = C; Spirogyra = S		C, S	C, S	S		C		∝
Fungi; Mucor = M, others = +; Bacteria = B	B	M	M+	M+		M		+
Archegoniates; Moss = M; Liverwort = L; Fern = F		M	L+			F		F
Relation of plants to environment	+		+	(alt.)	+	esp.	+	+
Rana, as type; systems and functions	(alt.)	+	+		Very general; no set types, but suggestions	+	+	+
Rana, development (externals only)		+		+				
Mammal, as type	(alt.)		skeletal	+				
Amœba	+	+	+	+		+	+	
Hydra = H; Worm = W	H	H	H			W	H, W	W
Insects; externals = e; life-history = l; dissection = d	e, l	e	e, l, d	e, l		e	e, l, d	e, l
Fish		+	+				+	+
Natural history (of certain types)				(alt.)			+	+
Relation of animals to environment	+		+			+	+	

otes: + means the subject is specified; esp., the subject is emphasised; alt., an alternative or option.

V. Out-of-School Activities in Relation to Science.

In response to a special request sent out by the committee many schools supplied information upon the various out-of-school activities ; the reports received show that science teaching owes much to the work done out of the ordinary school hours.

A natural history society exists in most schools. The older natural history societies are usually divided into sections : astronomical, natural science, ornithological, entomological, botanical, and so on, the interests of each section being supervised by curators or other officers. Physical and chemical sections may organise expeditions to works and factories, set up demonstrations illustrating phases of the development of the particular section, or undertake definite pieces of work in the laboratory. Geographical and historical clubs are fairly common, while in a number of rural schools bee clubs and gardening clubs are linked with the 'Young Farmers' Club' movement. To all such societies a camera club is considered a useful adjunct.

Under conditions where the time assigned to science is limited or negligible, as for example, on a few classical 'sides,' out-of-school science may be regarded, without exaggeration, as a saving factor in an unbalanced curriculum.

There seems to be variation in the conditions of membership. In the majority of schools boys or girls of all ages are eligible for membership, though the natural history society may be divided into senior and junior sections. In a few, membership is limited to the older pupils, while in others, active membership declines as pupils reach higher forms. Again, there are schools in which it would appear that the natural history society is run for the smaller boys only, and the old function of the natural history society is regarded as having been largely superseded by biological teaching.

It is evidently becoming more possible for boys to take part in out-of-school activities other than organised games. The clash of interests that has ensued between games and other out-of-school activities is diminishing, probably because many heads of schools exercise wise supervision over the activities of all departments, and realise their obligation to maintain a proper balance between them. One hears less of the obstacles raised because younger pupils must perform house duties or because senior ones are impeded by convention.

Several heads have emphasised the value of organised holiday camps, either for week-ends or longer periods. They point out that this enables members to spend periods in contact with countryside or seaside, to the benefit not only of the work but of the whole life of the school.

As a development of the principle of doing service to the community, one school, at least, sets up experiments and exhibits that are demonstrated for the benefit of adjacent schools and adult evening classes, while another school provides surplus biological material for others less fortunately situated.

The records of the societies, whatever their purpose or mode of organisation, demonstrate that, as a general rule, the pupils do most of the work and bear much of the responsibility, and further, that the work has a depth and quality that must reflect most beneficially not only on the scientific training of the individual but on the whole educational outlook of the school.

It is clear that many schools have undertaken pioneer work, and have thus made some contribution towards breaking down the artificial boundary between indoor and outdoor activities.

The following is a summary of the information obtained by the committee :

School Societies.—The science club often embraces all the sciences so as to give boys or girls, especially those who are specialising in non-scientific subjects, a chance to listen to lectures and debates on scientific subjects of current interest. It provides for the display of films of scientific appeal in natural history, archæology and other subjects. Lectures by visitors from other schools and from universities often provide great interest. Sections devoted to particular branches of science appeal specially to the field worker and the collector ; they give opportunities for the more enthusiastic members to read papers or, less formally, to describe or exhibit natural phenomena in the knowledge of which they are versed. Interest in the weather is fostered by the regular recording of meteorological observations. A combination of zoological and botanical garden for the use of pupils is a great asset ; skilled guidance is necessary here, but much of this work can be done by suitable chosen curators. In this connection it is interesting to read the report on the Botany Gardens of the James Allen's Girls' School, Dulwich (*Educational Pamphlet No.* 41, Board of Education). A room in which special collecting apparatus and aquaria, both large and small, can be kept is desirable ; but experience shows that work need not be delayed on account of the lack of such accommodation. For more advanced field-work a laboratory must be open at suitable out-of-school times. This kind of work is very valuable as a training in scientific method, provided the workers keep accurate records of data relevant to their observations.

Lectures of general scientific interest may well be thrown open to the whole school, and not limited to members of a society. In the North-Western area the Association of Women Science Teachers has a panel of lecturers who visit schools in the Manchester and Liverpool districts. The lecturers are chiefly teachers in secondary schools or University lecturers or museum keepers.

Many school museums are organised to help those interested in particular branches of science. The use of the material in the museum is encouraged and interest aroused by frequent changes in the exhibits. The possession of a museum, however good, offers little stimulus unless the pupil is already interested in field-work.

According to an experienced teacher of biology there are three stages through which boys will usually pass during the course of their membership in the science club, though not all boys will arrive at the third stage : (i) casual interest ; (ii) enthusiastic collection ; and (iii) a stage at which the work is pursued on scientific lines.

Unorganised Voluntary Holiday Work.—Where the school has scouts or guides much useful work is often done under competent leaders. The Whitsuntide and Summer camps are the means of introducing many urban pupils to some of the secrets and joys of the countryside.

Expeditions.—These may have as their primary objective : (i) the cultivation of a wider scientific outlook than class teaching can give ; (ii) the establishment of an interest in the practical application of scientific knowledge to human affairs ; and (iii) the acquisition of a first-hand experience of field-work. Under (i) and (ii) would be included visits to factories, gas and electrical stations, wireless stations, dairies, research stations, and zoological and botanical gardens. Managers are almost invariably generous in granting facilities for such visits, as well as in providing skilled guidance. Under (iii) would be included short expeditions into the country for the purpose of studying the flora, fauna and physical features.

From the administrative point of view, expeditions may be divided into (i) class expeditions in which a whole class takes part, either in school hours or on a holiday ; and (ii) voluntary expeditions undertaken for a like purpose by groups of pupils from different forms.

The best results are obtained from biological expeditions if in any one year attention is concentrated upon one or two localities only, and visits are made at different seasons. Casual expeditions, however enjoyable, are liable to be relatively unproductive. It is recommended that before the expedition each pupil should be provided with or should make a map of the region to be studied.

Longer voluntary expeditions call for expenditure and are less easily arranged ; where they are practicable they justify the trouble involved. Some schools arrange a week in the neighbourhood of Port Erin, and while studying the flora and fauna of the seashore they are also able to see the aquarium, museum and laboratories of the Marine Station there. Similar expeditions are made to the Lakes and to Derbyshire. Other schools arrange holiday courses in conjunction with the Marine Laboratories at Plymouth and at Millport ; while a less advanced course has been devised for younger boys at Colwyn Bay during the summer holidays. The biology mistresses of several London schools take girls to Seaford for a like purpose in the Easter holidays. All teachers of biology who have organised such expeditions have found them both useful and enjoyable.

VI. Summary and Conclusions.

There has been in recent years a definite but relatively slight increase in the biological content of school science courses, and good pioneer work is being done in the teaching of General Science.

There is ample evidence that, on the whole, Biology is being taught with skill and enthusiasm. The same may be said of General Science, though in a few cases the criticism may hold true that the teaching tends to be diffuse and generally to lack scientific character.

There appears to be a general feeling of growing intensity that the traditional chemistry and physics or botany of the secondary school is insufficient educationally, and that instruction in biology should claim a portion of the time available for science. Many arguments in favour of its inclusion are given in the historical review.

There does not seem at present to be any very definite agreement whether the biological part of the science course should come early or late in a child's school life. Many teachers would prefer it to be taken in the latter part of their school life, so that an adequate foundation of physics and chemistry can be assumed. Others think that at an earlier age the pupil's interests will be most easily awakened, and that the work will be less stereotyped by shadows of impending examinations. In some schools a compromise is effected between these two opinions—viz. that a considerable amount of biology and nature study is advisable and possible in the earlier years, between 11 and 13, and the subject dropped except for incidental references in relation to both chemistry and physics until the age of 16, when the child's experience enables it to appreciate the more important lessons biology has to teach.

The influence of examinations has been restrictive, so that in many schools intensive study of some parts of a subject has displaced the conception of a more liberal scientific education.

There seems no reason to think that the introduction of General Science into schools will render the science teaching more costly.

The chief causes of the neglect of Biology in schools are said to be :

(*a*) The apparent absence of any strongly expressed demand from parents and others interested in education.

(*b*) Inertia and lack of initiative in the face of established custom in schools in which only chemistry and physics are taught.

(*c*) A shortage of teachers who have studied biology during their University career.

When a sufficiently strong demand develops there is plenty of evidence that many teachers will be willing to acquire the necessary knowledge. Some Local Education Authorities and other bodies have already organised holiday and evening classes to meet this end.

Out-of-school activities form an important part of the science teaching in many schools. It is satisfactory to note that the need for caution against indiscriminate collecting of biological material is being emphasised and the desirability of making adequate provision for such material encouraged.

Conclusions.—We suggest that :

General Science should be taught in all secondary schools and on all ' sides ' of such schools, inasmuch as a knowledge of General Science forms an essential part of a liberal education. It should be regarded as an essential element in a school curriculum, and after the lapse of an agreed number of years no School Certificate should be granted unless the school is certified as efficient in this respect.

A course should not be called General Science unless it provides a co-ordinated survey of physics, chemistry and biology, using these words in a wide sense. The essential features of such courses should be constant emphasis that Nature is not partitioned into special sciences but that practical problems can be attacked by a scientific method which is much the same whether, for convenience, the problem is considered in terms of one or other particular branch of knowledge. The technique of the sciences must often differ, but every teacher should take care to draw attention to their essential unity of outlook.

So far as is practicable under the present system of School Certificate Examinations, the teaching of General Science should take place free from the restrictive influence of examinations. It is especially important that when General Science is taken in all schools there should be wide liberty of choice of emphasis so that teachers may follow to some extent their own interests and make full use of the school environment. Care will be necessary to avoid inexact and unscientific teaching when a very wide syllabus is in use.

University authorities responsible for the conduct of University Entrance Examinations in Science should demand that those candidates who propose to proceed to a degree in Science should have received a preliminary groundwork of General Science.

A more intimate system of co-operation between school and school might overcome many of the difficulties of material and equipment experienced by some schools in the teaching of biology.

There is a shortage, not so much of qualified botanists and zoologists as of teachers who possess the particular kind of ability and training necessary for the making of efficient teachers of biology.

General Science demands in a teacher wider knowledge and understanding of scientific procedure than the specialist subjects do. To be effective and stimulating the teacher must have real experience of the practical side of all three main divisions of the subject—biology, chemistry and physics.

VII. Thanks.

For their valued assistance in supplying the necessary information the best thanks of the committee are tendered to the—

(1) Heads and Science Teachers of individual Schools ;
(2) Assistant Mistresses' Association ;
(3) Association of Women Science Teachers ;
(4) Assistant Masters' Association ;
(5) Headmasters' Conference ;
(6) Incorporated Association of Headmasters ;
(7) Science Masters' Association.

SCIENCE TEACHING IN ADULT EDUCATION.

Report of Committee appointed to consider the position of Science Teaching in Adult Educational Classes, and to suggest possible means of promoting through them closer contact between Scientific Achievement and Social Development (Prof. J. L. Myres, F.B.A., *Chairman* ; Mr. C. E. Browne, *Secretary* ; Major A. G. Church, D.S.O., Dr. Lilian Clarke, Miss E. R. Conway, C.B.E., Prof. C. H. Desch, F.R.S., Sir Richard Gregory, Bt., F.R.S., Mr. S. R. Humby, Miss H. Masters, Mr. E. R. Thomas. *Co-opted :* Mr. A. Clow Ford, Dr. C. W. Kimmins).

CONTENTS

I. Introduction

One of the most direct reactions of general culture to industrialisation was the establishment, in the greater centres of mechanical production, of ' Mutual Improvement ' Societies, Literary and Philosophical Institutions, and (rather later) of more specialised Field Clubs and Natural History Societies, side by side with Archaeological and Architectural Societies, the offspring of the romantic movement which was so closely linked historically with the industrial. Most of these associations were literally for ' mutual improvement ' ; the best informed or most voluble amateur lectured to the rest ; apparatus was home-made ; where a ' magic lantern ' was available, the slides were hand-painted. London was far off. When the British Association was founded in 1831 it was explicitly to bring leading scientific men from London and the Universities into occasional conference with local workers, as well as local workers with each other.

It was in the subsequent half-century of this movement, thus assisted by the British Association, that quite naturally the great period of popular awakening to the value of science took place. The great controversies of the period, at times passionate and dramatic, fired popular imagination and enthusiasm, and gave force and power to the claim that science should find

its way into the curricula of established teaching. The result was the establishment of many new institutions with an almost exclusively scientific outlook. To such an extent, indeed, has ' science ' been accepted as an element in national life that some have actually asked whether the British Association has not now fulfilled the function for which it was called into being.

But such a view is facile : for while it is true that the establishment of the younger Universities, University Colleges, Technical Colleges, and so on, offer facilities almost undreamed of in the half-century following the foundation of the British Association, these facilities (along with which must be reckoned also a great deal of ' science ' teaching in schools of many different types) by reason, perhaps, of one of their main virtues—the insistence upon the rigour of exact laboratory methods—have failed to reach effectively a large section of the population ; and notwithstanding these great facilities, the number is probably still large who, by reason of geographical circumstances, of mental aptitude, of temperament, and of upbringing, regard science and its works with casualness, suspicion, and hostility—even with contempt.

This body of people has long offered a field for investigation, and a problem for which, perhaps, solution would not be easy ; a field and a possible problem, however, that come very definitely within the special purview of the British Association. What can be done for those whose early training left them uninterested in science, or critical of it, or whose daily work has prevented them from actively maintaining their interest by means of institutions with laboratory facilities ?

Meanwhile, that older provision of ' mutual improvement,' through local societies and institutes has, for the most part, given place to modern urban Universities and Technical Colleges. What remains has been drained of its energies by the concentration of scientific workers into centres of endowed research ; by improved access to London, and the growth of provincial public libraries ; and unfortunately, also by the inclusion of formal scientific studies, and even of what has come to be called ' nature study ' among ' school subjects ' ; voluntary work, and original observation and experiment, have been domesticated and systematised ; and with other social changes has come, in some field clubs, some restriction of the social range of customary membership ; with the result that much accommodation and even equipment is no longer put to full use, or even to its original purpose of the ' mutual improvement ' of artisans.

There were positive reasons, too, for more rapid growth of organised ' adult education ' in literary, historical, and economic subjects than in scientific With these the present inquiry is only concerned in so far as they show that the number of adult classes in science is relatively rather than absolutely small. Not many votes are needed to decide whether a centre shall devote itself to science or to an ' arts ' subject ; and the choice of subjects is in practice much wider in ' arts ' than in ' science.'

There has evidently been, however, a general impression that scientific subjects have not recently held the place in adult education that might have been expected in view of the large (and ever-growing) influence of scientific achievements on the general course of events, and especially on social development.

The *Place of Science in Adult Education* has, indeed, been the subject of several inquiries already. At Newcastle in 1916 the British Association received and discussed the report of a Committee (appointed in June of that year) on the *Popularization of Science through Public Lectures*, and its Secretary, Sir Richard Gregory, pressed home the main argument of this

report in his Presidential Address to Section L at Hull in 1922. Meanwhile, in 1921 the Board of Education constituted its Adult Education Committee, and this Committee's *Report No.* 8, on *Natural Science in Adult Education*, appeared in 1927. The Sixth Annual Conference (1927) of the British Institute of Adult Education dealt expressly with *Science and Adult Education* and published its proceedings in full. In 1931 the Workers' Educational Association, at its Annual Conference at Nottingham, considered 'the possibilities of stimulating further interest in the study of science on a non-vocational basis'; and its Executive Committee's Report (*Central No.* 198A) on this subject was presented in February 1932.

In addition to specific suggestions to its own District Secretaries, and general recommendations as to wider use of films in science courses for adults, that Committee strongly endorsed the opinion that 'within the restrictions imposed by the interests of the students and the conditions of work . . . the primary function' of science teaching in tutorial classes 'is to make the student acquainted with the broad outlines of the great scientific principles exemplified in familiar phenomena and applied to the service of man.' Further 'our classes in natural science should quite definitely be of a character which will tend to attract the uninitiated. We do not wish to cater for the members of scientific societies, etc., to the exclusion of the ordinary citizen, who has little or no scientific knowledge. What we desire, is to see our classes take the form more of a study of the action and reaction between scientific knowledge and social life. We feel that it is only in relation to the question as to how far and in what ways natural science influences and affects society, that our classes can maintain their interest in subjects of this character.'

During the summer of 1932 the Workers' Educational Association suggested to the British Association that some kind of joint committee might usefully discuss the place of science in adult education, with a view to more extensive work. At the York meeting the Educational Science Section regarded this project as part of the larger question of promoting closer contact between scientific achievement and social development, and recommended the appointment of a Committee 'to consider the position of Science Teaching in Adult Education classes, and to suggest possible means of promoting through them closer contact between scientific achievement and social development.'

The Committee's first task was to ascertain by direct inquiry the amount of progress made in the establishment of science classes during the six years since the Board of Education published their Report on the subject in 1927. Accordingly, a questionnaire was sent to the Board of Education, the Extra-mural Departments of the Universities of Great Britain, the Education Department of the London County Council, the Workers' Educational Association, the British Institute of Adult Education, the Young Men's Christian Association, and to many other institutions promoting and controlling Adult Education, as well as to individuals interested in it. The main points to be ascertained were:

The present position of science teaching in adult classes for non-vocational studies, and the conditions limiting or inhibiting increase in the number of courses in natural science.

Particulars of the organisation and policy of various bodies controlling and promoting such courses.

The methods usually adopted for obtaining teachers suited to adult teaching of natural science.

Means adopted for popularising science studies among adult students.

The supply of science books, equipment, and materials.

Bibliography of science teaching in adult education.

Details of any interchange and comparison of field work and other observations conducted by adult classes, especially in regional studies and in co-operation with existing Field Clubs and Philosophical Societies.

The replies were accompanied by many valuable memoranda, and in addition the Committee have had access to two important surveys recently completed :

(*a*) On *Adult Education in London*, undertaken by the London County Council in response to a questionnaire from the Board of Education in 1931 and now incorporated in *Paper No* 11 of the Adult Education Committee of the Board.

(*b*) On the *Study of Science in Adult Classes*, by a special Committee of the W.E.A., published in 1932.

The Committee feel, therefore, they are in possession of the latest data available, a digest of which is given below. They gratefully acknowledge the valuable assistance they have received from many who have readily and ungrudgingly responded to their requests for information. A complete list of those from whom memoranda and letters have been received will be found in the Appendix.

II. Abstracts from Replies to the Committee's Questionnaire.

The replies to the questionnaire may be most conveniently dealt with under the following headings :

1. *The General Organisation and Control of Adult Education in Great Britain and Northern Ireland.*

The agencies through which Adult Education in this country is carried on form a complex organisation, and vary remarkably in different districts.

There are three principal agencies: the Extra-mural Departments of Universities and of University Colleges, the Workers' Educational Association, and the Local Education Authorities. Working with these or independently are other bodies, of which the chief are: the Young Men's Christian Association, the Educational Settlements Association, the National Industrial Alliance, the Adult School Union, the Co-operative Union, and the National Federation of Women's Institutes. Besides these a number of Colleges are recognised under the Adult Education Regulations for grant purposes: the Ruskin College, the Catholic Workers' College, Fircroft College, Hillcroft College, and Coleg Harlech for residential students; the Working Men's College, and Morley College for non-residential students; also Mary Ward College, Toynbee Hall and others.

Co-operation between the principal bodies is through Joint Committees consisting of representatives of the Universities, the W.E.A., the L.E.A., and other associations or societies of a district.

The Adult Education Committee of the Board of Education exercises an important coordinating influence, through its Adult Education Regulations for the award of financial assistance. Local Education Authorities are more and more directly promoting Adult Classes, in addition to assisting local Joint Committees by grants of money or by providing rooms, teachers, and equipment free of charge.

Full particulars of these bodies and their inter-relationships are supplied by the Adult Education Committee of the Board of Education in its Paper No. 9, *Pioneer Work and other Developments in Adult Education*; Paper No. 10, *The Scope and Practice of Adult Education* (1930); and Paper No. 11, *Adult Education in relation to the Local Education Authority* (1933). The last-named contains an interesting history of the Adult Education Movement. It traces the development from the earliest Night School at the beginning of the nineteenth century to the complicated structure of Adult Education organisation of the present time; and describes fully the schemes under which Adult Classes are organised and maintained in different districts throughout the country.

The arrangements made for Adult Education within the University area of Bristol will serve as an example of the co-operative organisation between various bodies interested:

'In the University area, which covers the cities of Bristol, Bath and Gloucester, and the counties of Gloucestershire, Somerset, Wiltshire and a part of Dorsetshire, there is a co-operative scheme between the various Bodies concerned in Adult Education including the University of Bristol, the Local Education Authorities, the W.E.A., the Y.M.C.A., the Adult School Union, the Rural Community Councils and various Bodies. Under this scheme any type of class can be provided from a single pioneer lecture to a full tutorial class or extension lecture course. Some 80 short courses of four to six lectures are given in villages, and the W.E.A. provides over 100 terminal and one-year courses. During the present session there are 18 University Lecture Courses and 30 Tutorial Classes financed by the University.

'There is a Consultative Committee composed of representatives of all the Bodies concerned in each county. Tutorial Classes are organised from Bristol by a Joint Committee of the University and the W.E.A. Extension Lectures are organised by the University directly.

'The Courses for which the University is responsible are financed from four sources: Grants from the Board of Education, grants from the Local Authority, fees from students attending the Courses, University Grant to make up the deficiency.'

Two institutions which are concerned with adult classes for women only have so far not considered the question of science teaching in any form, viz., the Women's Institutes and the Townswomen's Guilds.

The instruction given in the Women's Institutes has been mainly of a practical character, but their aim is to develop a sense of citizenship and spirit of social service. The general secretary, the Hon. Frances Farrer, expresses the view that as these aims become more fully realised there is likely to be an increasing interest in and desire for further knowledge of scientific developments in relation to social and practical matters. She stresses the view that success would be likely to depend largely on the ability of the lecturer to approach the subject from the practical aspect and to deal with it in a non-technical and interesting manner.

The Townswomen's Guilds are still in process of formation. It is intended that they should take the place, in the towns, of the Women's Institutes in the country. A Central Committee divided into sub-committees for Civics, Handcrafts and Homecrafts, is considering the question of programmes and the publication of a monthly journal, *The Townswoman*. It seems possible that these Guilds might in future provide a field which has as yet hardly been touched for arousing an interest in science in relation to practical and social problems. (See also *Suggestion* 9, p. 356.)

2. *The Present Position of Science Teaching in Adult Classes.*

In the Board of Education Report (1927) on *Natural Science in Adult Education* it is noted that, ' compared with the growth of interest in English Literature, Music and the Drama since 1921, there has been no corresponding growth in the number of classes in Natural Science.'

Statistics collected in the course of the present inquiry show that there is still a strange neglect by adults of this branch of study, compared with such subjects as Literature, History, and Economics. The number of Science Courses is not more than approximately 6 per cent. of the total number. Taking the Board of Education figures for the same period and referring only to those courses accepted under the Adult Education Regulations, the percentage of science classes for the whole of England and Wales is 4·6 per cent. The Extra-mural Department of London University reports :

' Out of a total of 1,009 courses and classes in the years 1926 to 1932 only 41 were on science, viz., Biology 19, Anthropology 15, Astronomy 3, History of Science 2, Physiology and Hygiene 1, and one course of a general character, " Science and Daily Life." The average attendance at the courses was small. In University Extension Courses in general an average attendance of 60 to 70 is usual in the London district ; but for science courses within the same period named it was less than 40. The limited interest shown by the public, even when a science course is provided, undoubtedly discourages Local Committees responsible for the organisation of University Extension Courses from choosing this subject.'

In Durham and District ' attempts to form classes for the study of scientific subjects has met with little or no response.'

In 1930 the Co-operative Union included over 2,500 students of such subjects as Industrial History, Economics, Public Health, Local Government Taxation ; through their associated Guilds the Union is in touch with a large field of educational work, e.g. the membership of the Guilds was in that year 61,000 in England, and 27,000 in Scotland. The reply of the Secretary of the Royal Arsenal Co-operative Society (Educational Department) that ' there is no demand for science,' suggests how little science is considered as one of the determining factors in social developments.

2A. But while this may be true for a large number of districts, it is not true of all. An Extension Lecturer of long experience believes that there is everywhere a real demand for science, properly handled, and attributes the falling off in attendance at University Extension Lectures since the war largely to the financial stringency of the times. Other memoranda point to a distinct awakening of interest in science studies. From Loughborough College the report is optimistic :

' Statistics show there is a real demand for science classes and that it is growing. Moreover, the comparatively high standard of attendance and work attained by science classes is a marked feature of adult education in Leicestershire. The study of science in our villages is likely to increase considerably during the next few years, and every effort will be made to provide the right kind of tutor.'

Mr. S. Myers, Head of the Deptford Men's Institute, writes equally emphatically :

' I have thirteen years' experience with further education amongst working men in London following a year or two with similar groups of working men in Lancashire behind my opinion that there is no lack of interest in natural science. On the contrary, I have observed—particularly since about 1920—a swing away from social, economic and political interests towards scientific interests.'

A steady increase in the number of science classes is reported from the Western districts of the W.E.A. organisation, of which the Universities of Bristol and Glasgow are the respective centres, although relatively to other subjects the numbers for science are still small. The Extra-mural Department of Queen's University, Belfast, also reports a steady and an increasing demand.

' There is at present a substantial demand in the West of Scotland for adult classes in natural and physical science, the only subject group in which there is a markedly larger demand being English language and Literature ' (*Glasgow*).

' It is difficult to measure the exact extent of the demand for science studies.' In most classes, however, ' there are students who are interested in such studies even where there are not a sufficient number of students to justify the forming of a class. The demand (in Dorset) for science courses of an elementary and general type exists quite definitely, and is probably growing ' (*Bristol*).

In the Y.M.C.A. organisation there is said to be a considerable demand for presentation of scientific subjects in a non-technical and popular form. ' This demand is being met mainly by popular lectures, either in short courses or series, or in a programme of miscellaneous, popular lectures.'

Our general impression is that the actual demand for science teaching is small in most districts, almost non-existent in some, but growing and becoming quite considerable in several, especially in parts of the Midlands and in the Western districts of England and Scotland.

2B. Many experienced observers record the opinion that a much larger latent demand exists, but that there are limiting and inhibiting conditions, not easily removed. In the W.E.A. Science Report (1932) it is suggested that ' the lack of interest may be more apparent than real owing to the fact that Courses in Natural Science have seldom appeared in the lists of possible subjects, with the consequence that any potential interest in such subjects has not been cultivated.'

A reason for this is given by other writers :

' The initiative in arranging classes is taken by one or two educated people

who are interested in adult education, and if they, as frequently happens, have a purely literary outlook, science classes will not be chosen. . . . The logical and experimental technique of science is now so specialised that ordinary men and women tend to accept it as beyond their comprehension, and are discouraged by the circumstance that the point at which they must begin their studies appears very remote from the results which arouse their interest. . . . The reason for the comparative lack of development of science studies in science classes in the country generally is, I think, primarily the failure of those responsible to put the case to prospective students. In spite of the tradition that the adult education movement exists to satisfy the spontaneous demands of students themselves, groups are very anxious to have suggestions made to them, and are apt to be influenced by those suggestions. Since the organisers themselves are frequently interested in economic and social problems, that tends to create a bias in favour of those subjects. There are, however, difficulties connected with the teaching of science which do not affect other subjects; and that also must be regarded as a reason for the backwardness of this side of the work. (Prof. R. Peers, *Nottingham U.C.*)

A report on the position of science teaching in Adult Classes in the United States of America shows a somewhat similar attitude on the part of the general citizen. The Secretary of the American Association for Adult Education writes :

'I do not feel that the evidence is at hand to support the belief that there is an actual indifference to natural science subjects on the part of American adults. As a matter of fact, such evidence as exists points in the other direction, for our science lectures, where offered, are usually extraordinarily well attended and the interest expressed is keen. I feel quite sure that the relatively unimportant place held by science subjects in the adult education offerings in this country is attributable first, to lack of adequate financial support; second, to the lack of availability of qualified teachers at the secondary level; and third, to the lack of interest in adult teaching on the part of qualified teachers of science at the collegiate level. In the past the attitude of the research staffs of our universities and scientific institutions —the Carnegie Institution of Washington would be a notable exception— has been to avoid adult teaching of scientific subjects wherever possible on the ground that such "popularization" of necessity involved vulgarization and consequent loss of dignity to the research profession.'

3. *Conditions adversely affecting the Adoption of Science Subjects.*

The poor response to science courses is probably due to many conflicting causes. The chief of those adversely affecting the growth of science teaching in Adult Education may be stated under the following headings, but it must be realised that they are intimately linked in their effect, and form a very complex problem for organisers.

(*a*) The apparent remoteness of the exact sciences from every-day experiences, and the lack of mathematical training in many who are interested.

(*b*) The general absence of any real knowledge of science in the average adult, who therefore does not manifest much keenness about attending a class owing to a tendency to regard science as a study for 'clever' people only.

(*c*) The difficulties of providing adequate accommodation and equipment, even for ordinary demonstration experiments by lecturers or tutors; still more for any practical work by the student.

(*d*) The difficulties of obtaining an adequate supply of suitable lecturers and tutors.

3a. *Apparent Remoteness of the Subject.*

It is becoming more generally realised that formal courses of work on various branches of science, such as elementary physics or chemistry, are misdirected and unattractive, lacking in essential elements of Adult Education. They fail to awaken interest or understanding, and lead to an entire misconception of the practical value of science studies. On the other hand, in all cases when the approach is made along popular lines—when the courses deal, frankly and simply, with the real issues of life, and touch the everyday experience of the students—classes are well attended and high enthusiasm is engendered. Indeed, the testimony of many experienced teachers shows that starting with these simple natural interests the work has frequently developed a high standard of study, and led to the formation of clubs and societies that have done good work along both social and scientific lines in the most unlikely neighbourhoods, and often under very discouraging conditions.

'The general public regards science courses as too technical and specialised for them to understand . . . as too remote for ordinary life to interest them. . . . The great majority of people are not interested in botany *qua* botany, or in zoology *qua* zoology, but they are interested in the human and social applications of botany and zoology. . . . Most people are not interested in data, but in principles and generalisations. . . .' (Dr. Brierley, *Reading*).

Dr. Brierley further draws attention to the type of lecturer who tends to kill interest at the outset by following too meticulously the details of a subject, to the exclusion of the more general aspects, and by using academic language or technical jargon in place of pictorial terms in which to translate the messages of science. Compared with normal University education, he says, 'the approach must be made with different ideals, from a different standpoint, seen in a different perspective, and carried out with a different technique . . . the general public is keenly interested and wants to know what science can tell it, and what science cannot tell it of real life, but it has no use for academic futilities and unreal issues, which are so often put forward in answer to its demands.'

'The response to the science courses largely depends upon the method of presentation. Students are invariably attracted by a scientific lecture if care is exercised in the choice of title, and there is something to see as well as to hear . . . the adult student, without guidance, is very prone to select from those subjects offered which seem likely to throw light upon his immediate problems of life . . . hence the choice of economics and allied subjects in the first place.' On the other hand, 'If the scope of scientific classes is put before prospective students with the same degree of persuasive explanation that is commonly used with other subjects, then a greater response would equally follow' (Dr. A. J. Grove, *London*).

'The ordinary man in the street is afraid of science. He knows nothing about the nature of science' (Dr. Norman Walker, *Leeds*). For this reason he strongly urges the need to bring the students right close up to things, to do experiments themselves and so learn through their own interested observations the real meaning of science. His method is fully described in a paper published by the British Institute of Adult Education in their Report of the Conference held in 1927.

'It is absolutely essential that every lecture should be illustrated either

by experiments or, when these are not possible, by plenty of specimens and lantern slides. I am certain that the experimental illustrations are some of the most important parts of the lecture, and the results obtained from them fully compensate for the time spent in collecting the necessary materials, for the difficulties of transporting everything required for the demonstration, and of carrying out experiments without gas, electric light, or a water supply. In districts where there is a considerable demand for science classes, and where courses are standardised, it would be possible for sets of apparatus and materials to be sent to each centre for the lecturer's use throughout the course, but this would not be worth while until the demand increased' (Dr. A. W. Chapman, *Sheffield*).

To remove the inhibiting effects of those conditions referred to in (*a*) and (*b*) above, lecturers and tutors need to approach their task in a very different manner from that adopted for the ordinary student of the university or technical college.

3b. *Lack of Elementary Knowledge.*

There is often lack of previous preparation of the students. 'Inadequate or unsuitable previous education is a difficulty in the case of some subjects, especially those requiring mathematics. This difficulty rules out Physics, Astronomy, etc., except as subjects for popular classes. It is impossible to have Tutorial classes in those subjects, since the work cannot be carried to a sufficiently advanced stage. The result is a tendency to concentrate on two main groups of subjects—Biology and Evolution ; and Chemistry, Health and Hygiene, etc. A good deal might, however, be done to develop the study of subjects such as Geology, Geography and Nature Study' (Prof. Peers, *Nottingham U.C.*).

3c. *Inadequate Accommodation and Equipment.*

Many correspondents refer to the difficulties under which science labours through inadequate accommodation and equipment. This was mentioned in the British Institute's Conference (pp. 332, 356), as 'prejudicial to the growth of the Adult Education Movement generally and to the increase in the number of science classes particularly.' The difficulty of securing satisfactory accommodation is still a serious obstacle. 'The want of suitable accommodation is often an adverse factor in the arrangement of science courses which require experimental illustration. Most courses and classes are held on premises not intended nor suitable for science work, and there are usually no facilities for the use or safe keeping of apparatus' (*London*).

Classes held in the L.C.C. Men's Evening Institutes are almost exclusively held in the evening, in premises occupied during the day, as a rule, by elementary schools. The limitations due to lack of equipment and accommodation wiil be obvious. At best, there is a 'practical room,' furnished with tables and chairs instead of the more usual classroom desks, and designed, not for science teaching, but for practical, or handwork of various kinds. Assuming, therefore, that there were a demand for serious science studies of a non-vocational type, this initial handicap would make it impossible to satisfy it under present conditions.

This difficulty specially applies in country districts, with few exceptions. It is only on University premises and in a few technical and secondary schools that any provision is made. In London, for example, with its Literary Institutes and well-equipped secondary schools under the L.C.C., the demand for facilities for science courses could easily be met for some

years to come. Similar advantages are found to some extent in other University cities. But outside these centres the difficulty of securing suitable accommodation and adequate supplies of apparatus constitutes a really big limiting factor in the organisation of science classes for Adult Education. In all the most active centres for science work this position is emphasised.

In Nottinghamshire, ' When classes in biology, chemistry, etc., can meet in a laboratory, it is possible to do useful work, but facilities of this kind are available only in the University towns or in towns which have a secondary school : even then it is not always possible to obtain the use of laboratories for adult classes. Many of the classes, however, meet in small towns or villages, and such elementary requirements as running-water and gas are rarely available in the classroom. Tutors have to take all their own apparatus, and work with buckets of water, spirit lamps, etc. It is little wonder they fall back to a great extent upon lantern slides, or occasional demonstrations, and the chief value of science teaching is lost to the students ' (Prof. Peers).

In Leicestershire, ' the provision of the necessary accommodation, equipment, and material is still very difficult. Most of the classes have to be held in village schools which are, of course, not designed to accommodate adult science classes. The resources of Loughborough College, however, are available for the classes held in Leicestershire, and we are now able to provide microscopes, a projector, and other equipment for the use of the tutors. Occasionally students have been brought in from a village class to have a meeting in the College, where more adequate equipment for demonstrations is available. Some of the tutors have cars, and carry a considerable amount of equipment to their classes. The students also provide some of their own materials for experiment ' (R. J. Howrie, *Loughborough T.C.*).

In Glasgow, provision is made to meet the demands for science ' largely through classes meeting at the University where laboratories are available. At most outlying centres it has not been found possible to meet it so fully, most of the equipment found necessary, in so far as it could not be provided by the students themselves, has been taken from Glasgow.'

At Bristol, ' there is a certain difficulty with regard to equipment. This does not apply in Bristol, where University laboratories are available. Outside Bristol, and other large towns, it is not easy to secure equipment, except for courses where instruments and material of a portable kind can be used.'

The result is a fundamental limitation to certain kinds, and aspects, of scientific study. One W.E.A. worker in Birmingham writes :

' The serious study of science by groups of working people is a new development in Education, and its point of departure is different from that in schools and Universities. . . . It is found desirable to begin, not as physics or chemistry, or biology, but with a mixed elementary introduction to all these. This, in itself, has proved difficult to fit in with the ordinary supply of apparatus, as it neither is a specialised science course nor hygiene, nor nature study. This kind of teaching makes different demands on equipment from the ordinary school or college course. It does not demand expensive apparatus, so much as different apparatus, with consequent need of storage place and opportunity for preparation.'

Even in London only three out of the twelve Literary Institutes organised by the L.E.A. for Adult Education attempt any classes in science, and only two of these possess any equipment for the work.

3d. *Difficulties in obtaining Supply of Suitable Teachers.*

The Board of Education Report (1927), p. 29, noted that 'the greatest difficulty which is likely to beset the adult education movement in this situation, is that of finding teachers of wide knowledge who are capable of inspiring interest in Natural Science as a study of the conditions of human action.'

The late Dr. Harold Wager pointed out that 'the success of science classes for adult students depends in a special degree on the character of the teaching and the personality of the teacher. It is more difficult to secure the right sort of teaching for adult students in science than in such a subject as Economics.'

From London, Mr. G. H. Gater (*L.C.C.*) writes:

'As regards teachers of science, it is found that, as is the case with teachers of any subject, some of them appeal more strongly than others to adult classes. The good teachers become known and their services are largely in demand. Others, through inexperience of the special problems, do not at first gain their audience, but under the guidance from the inspectors and heads eventually succeed. Others again have not the right appeal, quickly lose their students, and themselves drop out of the work.'

This difficulty of securing a sufficient supply of suitable teachers is shown by the evidence received by this Committee to be still a considerable factor in holding up the desired advance in science teaching.

The Secretary of the Oxford Delegacy for Extra-mural Studies writes: 'We could advance more quickly and more securely if we could get a better supply of really suitable tutors and lecturers for adult classes.'

Similarly the Secretary of the Cambridge Board (Mr. G. F. Hickson) writes: 'In adult education demand does depend to some extent on supply (of teachers). It might be very well increased if there were more lecturers and tutors capable of dealing with scientific subjects in a suitable fashion for this purpose,' but 'no special steps have been taken by the Extra-mural Board to attract and secure the services of suitable teachers.'

The Registrar for the London Extra-mural Department says:

'The supply of lecturers available for, and capable of, giving science courses intended for adult students for non-vocational purposes is undoubtedly limited, and this in its turn reacts on the demand. . . . Most science teachers of sufficiently high standing to attract the general public are too specialised in their work to be prepared to offer a course of the kind required.'

Prof. Peers (*Nottingham U.C.*) lays stress on the comparative scarcity of suitable teachers for adult science classes. 'Science teachers in Universities are usually extreme specialists with little interest outside their own subjects. In particular they usually lack human interests, and the teaching, therefore, is apt to appear arid and meaningless to groups of adult students whose interests are mainly social. Not only that, but their lack of outside interests and contacts makes it difficult for them to acquire the right technique of teaching. They are often less skilful as lecturers than those who have to depend mainly on the spoken word for the presentation of their subject. On the other hand, the possibility of using experiments and demonstrations undoubtedly gives them an advantage.'

Mr. G. C. Robson, British Museum (Natural History), ascribes the decline of popular interest in science to:

(1) 'Lack of good lecturers, due (*a*) to increased specialisation, and (*b*) to

the increase in remuneration of scientific workers which may have made it unnecessary for many to seek evening work to supplement their salaries.

(2) ‘ The rapid advance in all branches of science over the period under review ’ which ‘ may have tended to make the scientific worker obsessed with the pressing problems of his own job and little inclined to commit himself to popular audiences ; willing to deal with specialised matter to a University class, but not to a popular audience.’

On the other hand, those writing on behalf of the Local Education Authorities of London and Leicestershire, of the Extra-mural Departments of Bristol, Manchester, and Liverpool, of the Y.M.C.A., consider that at present the supply of suitable teachers is adequate for the demand.

With these conflicting opinions it is difficult to arrive at a just estimate, but it may be noted that on one side reference is mainly made to the supply of teachers to meet an increased demand ; on the other, to the supply of existing demand for science studies. Another opinion is that there is a wider and more numerous field for the selection of teachers where only lectures are required, than where tutorial work is to be undertaken ; a man who is quite a successful lecturer may not necessarily be so happy in the more intimate and less formal work of a tutorial class.

From the Extra-mural Delegacy at Oxford, Rev. F. E. Hutchinson makes the practical suggestion that :

‘ A panel of teachers suitable for adult classes in various sciences might be drawn up by the British Association, and that the University Committees should be allowed to communicate with the secretary of the panel when particular demands arise.’

4. *Qualifications and Characteristics of Teachers suitable for Adult Classes.*

Much evidently depends on what are considered to be the characteristics and qualifications of a suitable teacher. It is always possible to get plenty of teachers of various types, but it is another matter to attract men or women of the exceptional type required for the successful handling of science courses in Adult Education. Dr. Brierley (*Reading U.*) requires ‘ a man of personality and imagination, with a gift of speaking, and wide human interests in addition to his equipment of scientific knowledge, capable of always interesting a public audience even if discussing quite technical problems, of seeing things from their angle and in their perspective, possessing the power of speaking accurately, yet rather pictorially in simple, every-day language, always illustrating by facts and phenomena of everyday life and common experience, of speaking clearly and articulating his words distinctly, and of presenting his matter in a simple, logical form, so that connecting links are always clear.’

Dr. A. J. Grove (*London*) expresses similar views in a slightly different way :

‘ The tutor of a tutorial class has to be something very much more than a mere purveyor of facts, scientific or otherwise. His business is not so much to instil facts into the students’ minds as to cultivate an attitude of mind. A purely academic attitude on the part of the tutor is worse than useless in adult classes. In addition to a wide knowledge of his subject and a facility of presentation, it is important that he should have a wide experience of men and affairs, an outlook beyond the scope of his immediate topic, and be keenly alive to points of contact between the matter he is dealing with and everyday life.’

The problem is how to find such men, and when found how to induce them to devote their services to the Adult Movement. The problem

involves the consideration of career and finance, and turns on the question whether science teaching in adult classes should be a whole-time occupation or part-time. One aspect of the situation from the young graduate's point of view is that since such work does not lead to a career in itself it leads to a constant conflict of interest between the tutorial work whereby he gets his living, and the research work on which his future depends.

It is further suggested by Dr. Brierley (*Reading*) that :

' The whole-time teacher, separated as almost inevitably he must be from active research, or intimate contact with such research, would tend to lose his inspiration, and to become simply something of a gramophone record.' . . . On the other hand, ' most scientists holding posts in Universities, or in research institutions, already find their lives over-full, and have not the time and energy to devote to the type of missionary work required in adult education.'

Some difference of opinion has been expressed as to the best kind of experience and training for those who undertake adult classes. Oxford opinion is decidedly in favour of high university qualifications, and experience in university teaching, rather than in the employment of science masters, or of amateurs.

At Bristol : ' For University classes the standard adopted should be that lecturers and tutors should hold a good honours degree in the subject taught.'

At Glasgow : ' A high standard of knowledge of the subject, such as may be looked for in members of a University staff, while almost indispensable, is not the only essential. It is essential that tutors should be inspired by enthusiasm for their subject and should be capable of presenting it in such a manner as to arouse the enthusiastic interest of laymen. They must be capable, too, of appreciating the questions and the point of view of their students, remembering that neither interest nor the equipment of the adult student is ordinarily the same as that of the professional scientist, or of the University or Technical College student.'

At Liverpool ' the staff is selected by the University ; at present all members are of the internal University staff. The engagement is for one year and renewed for whole courses.'

On the other hand : ' The most suitable teacher is of the " general practitioner " type rather than the highly specialised. It is most important that lecturers should have kept abreast of modern developments in science ' (City Literary Institute).

' The outlook and qualifications of the teacher of adults will differ very considerably from those of the internal University teacher ' (Dr. Norman Walker, *Leeds*).

' On the whole, it is probable that secondary school masters are more hopeful material than university lecturers ' (L. A. Fenn, *Birmingham*).

The choice of teachers is the more important because, as Dr. A. J. Grove (*London*) puts it : ' The wrong kind of tutor can do so much harm. How to find the right one, is not easy to answer. If only our primary and secondary education was more concerned with " educating " and not so much with imparting erudition, then not only would there be many more adult students, but the right kind of tutors would be forthcoming. At present, apart from a radical change in scholastic and academic teaching, it is difficult to see how this problem is to be solved.'

One of the recommendations accepted by the Council of the W.E.A. and put forward by their special Committee of Inquiry, is that ' District Secretaries should prepare a panel of scientific lecturers and tutors in their areas who would be prepared to undertake either Tutorial Class work,

One-Year Class work, Extension work, or popular lecture work in Natural Science.'

Many men possessing the qualities desired would, no doubt, readily respond to an invitation to take charge of science courses, if the remuneration was sufficiently attractive and assured. The remuneration can be provided if the classes are sufficiently well organised and attended, because they can then earn the grant under the Board of Education regulations. But attendances depend on the extent of the demand for science. Hence follows the quandary—on the one hand it is the supply which creates the demand, and on the other that the supply cannot be provided until there is a sufficient demand to make it worth while.

5. *Aims and Purpose of Science Teaching in Adult Education.*

Several correspondents deal with the ' popularisation of science ' in adult classes. In this connection it is important to understand what are the aims of those who are already teaching science, as well as of those who wish to see the study of science more widely adopted in these classes. It is equally important to know what are the desires that prompt (or might prompt) an adult student to take up the serious study of any branch of Natural Science. These two factors—the aim of the teacher, and the purpose of the student —must meet somewhere in sympathetic co-operation, if a true appreciation of science by people generally is to be assured.

The Committee is not primarily concerned with the provision for vocational or technical training, but more particularly with the systematic presentation of scientific methods and results, both pure and applied. But it is realised that these two kinds of teaching often overlap in the same course and also that the aims and motives of teachers and of students vary.

' The purpose of the science lectures and classes in the evening institutes, and in other institutions referred to, is purely cultural. The aim is to foster the good use of leisure and to satisfy the wishes of those who seek to know something about science, what it has done for mankind and its practical application in matters of daily life ' (G. H. Gater, *L.C.C.*).

' If the important part taken by the Adult Education Movement in the national life is to be shaped in the light of the rapidity of the changes which are taking place owing to the increased application of scientific invention to modern production, it is essential that the education which it provides should be wide and liberal, and assign an adequate place in its scheme for the teaching of science. The Adult Education Movement cannot afford to neglect scientific thought and knowledge. Ignorance of the influence of science should belong to the past, and we can only be confident of future progress if we understand all the forces which are contributing to the re-shaping of social life ' (W.E.A. Science Report, 1932).

' The purpose of science teaching in adult classes is obviously not to turn out specialists or experts ; it is to make the student intelligently interested in the world in which he lives and to enable him to understand the fundamental facts of life. If he is taught to regard the world merely from the economic and political point of view, his thinking will be one-sided and incomplete. And the so-called ' cultural ' subjects, with no background of scientific method, frequently lead to slovenly thinking, and a smug self-satisfaction, which needs to be broken down by the discipline of scientific study ' (Prof. Peers, *Nottingham U.C.*).

' From the point of view of the organisers, science classes, like all other classes held under the Adult Education Regulations, are, in the words of

the Board's Regulations, 'designed for the liberal education of adults.' Such education must be something more than the imparting of information about particular topics, and in the case of science teaching, as distinguished from the teaching in literature and art, the purpose seems to be primarily to cultivate systematic, accurate and impartial study of natural phenomena. The teaching of science is concerned with the application of scientific method to the explanation of a particular group of phenomena, but the scientific attitude of mind is valuable in all studies, and the influence of science teaching extends beyond the limits of formal classes in science' (R. J. Howrie, *Loughborough T.C.*).

'The aim which I feel should guide science courses of this type is to arouse an interest in scientific outlook and method, to show what the application of science has done to afford a better understanding of the world, and a change in the conditions of human life, and to explain the function of the scientist in modern society' (Dr. A. W. Chapman, *Sheffield*).

'Regarding the purpose of the science teaching in these classes, I do not find that there is any marked divergence in the views of the organisers, tutors, lecturers and members of the classes. In some instances, however, an aim is implicit rather than explicit and a student who originally enters a class with one purpose in view becomes interested as his study proceeds in some other purpose which it serves. There is, too, a varying emphasis on the different aims as between one tutor and another, and as between different individuals within the class. The various purposes served by study in these classes are:

'(1) the provision of knowledge likely to be of interest throughout life, either through equipping the student for a leisure-time occupation, or by giving a wider meaning to the student's own vocation, e.g. where a golf-green keeper or park gardener studies general botany.

'(2) the apprehension of science as a great co-operative enterprise of mankind, the interest in science being part of the interest in human activity leading to the satisfaction both of the curiosity and of the gregarious characteristic of human nature. The study of science from this motive is likely to promote social solidarity, giving to each a sense of unity with his fellow.

'(3) through the study of scientific method to reveal thought processes and the need for and method of exercise of powers of observation, criticism and diagnosis. The achievement of this purpose is manifestly of great importance enhancing the value of the student both individually and socially.

'(4) to develop intellectual activity and to establish true self-confidence.

'(5) to trace the part which science and scientific achievement and method have played and may play in moulding human society of to-day.

'(6) to furnish experience which each individual may correlate with his whole experience to form his philosophy of life.

'(7) to form a bond breaking down barriers between different sections of society and different ages. Parents frequently take these classes to enable them the better to understand matters in which their children are, or may become, interested.

'(8) in some cases to promote efficiency in vocation.

'This last aim, while not the primary purpose of these classes, is quite justifiable, but it must occupy a subordinate place in adult education, and should not be allowed to determine the course to the detriment of the other purposes of such education. In this there may be a divergence in purpose between tutor and organiser and some members of the classes. Mention should be made of the equipment of students to play more efficiently their

part in working-class movements, an aim which has been present in the minds of many associated with the Adult Education Movement. But this purpose is achieved in the case of science through the other purposes, such, for example, as (2), (3), (4) and (5) above. Ability to understand the point of view of others which may well be fostered by such studies, may be considered as akin to (2), (3) and (7) above ' (D. M. Stewart, *Glasgow*).

Mr. S. Myers, Head of the Deptford Men's Institute, writing in the light of many years' experience, and entirely as a matter of personal opinion, says:

' At the L.C.C. Men's Institutes we adopt a special angle of approach. We have found it not only sound but essential to proceed from the immediate interests of the students or prospective students, and to build round them a progressive educational course. A few examples may make the attitude clear.

' (1) We have classes in ' Wireless.' These have their origin in the fact that most working-class homes possess a wireless set. Men talk wireless in their workshops, in public-houses, and elsewhere. Realising this, we invite men to meet a wireless expert once a week, thus focusing the wireless interest in a class. A syllabus is framed to ensure that the class makes a sound theoretical study of the subject.

' (2) The ownership of a motor-cycle leads to an interest in internal combustion engines, magnetos, carburettors, electric lighting, etc. Here again, men who own motor cycles or cars, or who aspire to own them, or who drive other people's cars, are drawn to classes in petrol engines (with car lighting, ignition, and starting) held in the Men's Institutes.

' (3) The widespread use of photographic apparatus leads in the same way to an interest in lenses, light, colour, and the chemicals used in the preparation of sensitised film and plates, and in the developing and printing of photographs. Hence classes in " The Chemistry of Photography " at several Men's Institutes.

' (4) Poultry, rabbits, cage-birds and domestic pets are extensively kept —by way of a hobby—in working-class districts. If fifteen or twenty men can be brought together by a desire to know more about these creatures, we open Poultry Keeping, Care of Animals, and similar classes.'

' In all these classes the instruction is at once practical and scientific. Rule-of-thumb is discouraged, and the object is—as my examples may indicate—to proceed from practice and observation to general principles and thence to the application of principles. The effectiveness of the instruction in poultry-keeping, for example, is observable in the extraordinary success of these " backyard poultry-keepers and breeders in competition with the poultry industry at the appropriate national open competitions and laying tests.'

Though vocational science is outside the terms of reference, the scientific basis of industry offers a promising field of adult education. Professor Julian Huxley writes that ' industrial work should be more directly linked up with its scientific basis; scientific work and invention should be encouraged among workers in factories, and knowledge of the scientific basis of the processes on which they are employed should be made more accessible to such workers.'

' The aim of the Adult Biology Class is *not* to produce naturalists—not more than 1 in 20 average adult student has the makings of a naturalist in him—but to make intelligent citizens capable of a scientific attitude towards public questions and their own personal matters ' (Dr. Norman Walker, *Leeds*).

The Joint Committee in Belfast, representing the Extra-mural Department, Queen's University, and the W.E.A., ' seeks to give its students knowledge which will enable them to utilise their leisure time in the best

possible way, and lead to the application of the scientific method to all problems of life.'

At Liverpool the teaching is ' purely non-vocational, and for purposes of wider culture.'

At Cambridge, in the Extra-mural courses : ' The teaching of lecturers and tutors is non-vocational in character and, broadly speaking, their aim is to interpret science to the layman and to relate scientific developments to daily life.'

Another aspect of the problem was discussed by Dr. Charles Singer (*London*). He traces the ' current distaste for science ' to defects in the history teaching of our schools. Starting from the agreed proposition that every adult should know the main results of science he specifies particularly the differences science has made, (*a*) in our way of thinking, and (*b*) in our way of living. These he characterises as the most important events in the history of the last 300 years.

He regards teaching of the nature of these differences or changes as one of the prime duties of a teacher of history, a duty which, in his opinion, the teacher grossly neglects.

The remedy for this distaste he considers ' to consist primarily in reforming the teaching that goes by the name of history, and making it essentially the history of civilisation. Until history teachers teach that the most important event of the last 300 years is the rise of science, they will continue to teach false history.' As this aspect of the problem is beyond the scope of this inquiry, he suggests that much might be done ' by attractive adult teaching on the nature and origin of scientific discoveries, and by making lectures centre round such personalities as Descartes, Harvey, Boyle, Galileo, Newton, Pasteur, Darwin, Davy, Faraday, Helmholtz, Fraunhofer, and so forth.' He advocates such ' lectures in which simple historical experiments could be repeated and their meaning developed in the field of more modern knowledge. Such historical experiments would give a human interest to science.'

To render these experiments most effective he suggests that ' arrangements might be made for lecture-demonstrations to last $1\frac{1}{2}$ or 2 hours rather than 1 hour, and that the experiments be performed by an assistant in the middle of the hall and away from the lecturer. Thus the audience might gather from time to time round the experimenting table and then return to their seats.'

6. *Aims and Motives of Students attending Adult Science Classes.*

The aims and motives of the students attending adult classes are less definite, and more difficult to interpret. They are probably very mixed, and change as their interest and knowledge increase.

' The motives which lead students to enter classes naturally vary. Some come from purely intellectual curiosity, others because they believe that science has an important contribution to make towards the understanding and control of modern civilisation ' (*Bristol*).

' The average Literary Institute student has neither time nor energy for acquiring a thorough knowledge of any science. He is interested rather in the conclusions which have been reached and in the theories which are being tested. He seeks to coordinate and synthesise his knowledge so as to reach an interpretation of experience which is satisfying to himself. It is impossible for him to follow out the detailed processes whereby the conclusions of science are reached, but he is intensely interested in scientific generalisations, which he can link up with his experience of life. This view

is common to organisers, lecturers and members of classes ' (City Literary Institute).

' Students are attracted to science classes by many different interests, and any generalisation about motives is likely to be more or less false. For instance, some come to biology classes because they are interested in the theory of evolution, probably from a philosophical angle ; some want to know something about plant or animal life ; others are chiefly interested in personal hygiene. In every case, however, what the students need is a grounding in scientific method ' (R. J. Howrie, *Loughborough T.C.*).

' Biology is by far the most attractive of scientific studies to members of Tutorial Classes, and, this being so, we have sought to find out why. We are of opinion that the particular attraction which Biology has for the adult student is due to the fact that it deals with matters within the student's own experience and observation, and have a close bearing on his daily life ' (W.E.A. Science Report, 1932).

An important aspect of biological study is noted by Mr. S. Myers (Deptford Men's Institute) : ' Interest in, and the growing practice of, contraception has given rise to a keen interest in generation and pre-natal development, in inheritance and in allied matters. Other causes may contribute to this result. I am not concerned with the ethical aspect of birth control, but I am definitely of opinion that married men need some expert guidance in what may be called the hygiene of married life, and that this should take the form of courses of lectures on biology conducted on lines much less oblique in relation to sex matters than the courses generally available under this name, i.e. biology. The working-class wife and mother probably suffers more from ignorance—her own and her husband's—than has yet been realised. We have left the most sacred things in human life, as far as they concern our poorer neighbours, to the academy of the gutter whose professors do their work tragically well.'

7. *Propaganda and Publicity.*

The problem of stimulating the demand for science studies in Adult Classes is a matter for those who realise the importance of the subject to the community generally and understand the serious danger to social stability that accompanies ignorance of the facts of science, or of scientific method. It is for those to suggest means for awakening interest in these studies and put them in operation. Several witnesses bear testimony that behind the apparent indifference to science suggested by the comparatively small number of classes, men and women are keen to learn when given the opportunity, and when they see that what is offered has practical bearing on the problems of life.

Since 1921 there has been very little active propaganda on behalf of science. Most organisers of Adult Education are concerned with providing what is asked for, and can hold no brief for any one subject. Such bodies as the Local Education Authorities, and the Boards of Studies of the Universities, naturally act for the most part, on the principle that, if and when demand for science courses arise, they will do their best to meet it, and will provide the necessary facilities.

' It has been the policy of the Council to meet the demand on the part of students for classes in any suitable subject. For some unknown cause science is, relatively speaking, not popular at present and, therefore, there has not been the same demand for science classes as for some other subjects. It is thought that an increased demand can only arise as the effect of science teaching in secondary and other schools becomes more marked and as

science is popularised by wireless talks, press articles, and so on. It will be realised that the present call for economy in public expenditure renders it necessary to go slowly as regards enlarging the scope of the Institutes, but the Council never refuses to provide classes where students in sufficient numbers present themselves ' (G. H. Gater, *L.C.C.*).

' Apart from the usual discussion of subjects with Extension Centres and prospective classes, no special propaganda has been undertaken in favour of scientific studies ' (Cambridge University Extra-mural Board).

' We have no definite scheme for extending scientific work in Adult Classes. As the demand arises we endeavour to secure teachers in the subjects asked for ' (W.E.A., Western District).

' Advertisements of special courses are issued and notices are sent out and meetings held, and groups likely to be interested are specially interviewed in the various centres with a view to the formation of classes and the organisation of courses of lectures ' (Manchester University).

Success in promoting Adult Education in science in the region served by a University depends much less on formal organisation than on the missionary efforts of individuals. In many parts of the country, especially in the North, successful classes in literary subjects have been built up, and a connection with the University thus established, so that means are available for introducing science into a community where the habit of study has already become familiar. In one instance a lecturer in the English Department of a University had been remarably successful in his efforts to establish classes under the W.E.A. over a large area, attended mainly by coal miners and metallurgical workers. He had a great personal influence on these groups, and at his suggestion colleagues from the scientific departments of the University were from time to time invited to lecture on their own subjects and always found large and attentive audiences. From these occasional lectures there has grown a more systematic scheme of scientific lecture courses, although practical work by the students has not yet been attempted.

Lectures on the history of local industries make an appeal to audiences in such districts. A group of miners will listen to and appreciate an account (illustrated by lantern slides and specimens) of the development of mining since ancient times, whilst steel workers can be similarly interested in the history of metallurgy. If care be taken to show the connection between the progress of an art and social conditions, the interest of industrial audiences, which usually leans towards the side of economics, can be aroused, and a bridge is thus provided leading to the teaching of science proper. It is possible that the social history of agriculture might be used similarly in some districts as an approach to biology. Compare what has been quoted above (p. 347) from Dr. Charles Singer as to the historical approach to science generally.

A teacher imbued with the missionary spirit, and having an influence on the extra-mural students in his region, can enlist the help of his university colleagues in the teaching of science. It is best that the first steps should be entirely informal. The panel of lecturers should be chosen by a few who know the region, and not by a committee or a public authority. The W.E.A. scheme is elastic, and the extra-mural side of the universities is not usually greatly hampered by red tape. The teachers selected must, however, have a real evangelical fervour, if they are to succeed. Sometimes it may be a senior man who has become impressed in the course of his experience by the urgent need of more scientific knowledge on the part of the public ; sometimes it may be an enthusiastic junior lecturer who has the gift of popular exposition, who will best fill the place. Such men are not common

at present, but the experiment must be made slowly, and when a demand has once been established, an increased supply of suitable teachers may be expected.

' Pioneer work in the form of lectures, either single or in the form of a series, by the right kind of tutor, always attracts a number of potential students. And having got their interest, never let it flag. The subject-matter dealt with in these lectures must be of the right kind and be of immediate interest in relation to everyday things. The method of presentation must be simple, but scientific (not popular) and calculated to whet the appetite for more ' (Dr. A. J. Grove, *London*).

' More propaganda among voluntary organisations engaged in some form of adult education would encourage the development of scientific teaching. For instance, the study of the drama has been fostered by the Rural Community Council. There seems to be no reason why this and similar organisations might not foster the study of scientific subjects. This observation also applies to the special interest in social subjects on the part of the W.E.A. ' (R. J. Howrie, *Loughborough T.C.*).

' There is need for expository lectures of a non-technical type as a means of propaganda for more intensive work ' (*Bristol*).

' A demand can perhaps more easily be stimulated in the first instance for such a subject as Nature Study than for a more specialised branch of science. In the University staff the specialisation necessary on the part of those engaged in science teaching makes it somewhat difficult to get tutors who will deal satisfactorily with this subject, but tutors may probably be obtained from other institutions where a more generalised treatment of science is combined with requirement of a suitably high standard of attainment. Like Nature Study, Astronomy is a subject likely to prove suitable for introduction in a centre where a demand for science classes for adults has not yet revealed itself.

Broadcasting, journals, and other media of propaganda have also a part to play in extending interest in the study of science. So also have contacts, largely of an informal type, e.g. in outings, with various organisations which are interested in younger adults. Mechanical aids may be of considerable value in making a lecture more attractive, a point of particular importance in a pioneering lecture. But the enthusiasm of a competent lecturer is, in pioneer work, an asset for which no adequate substitute can be found. Full publicity must, however, be given to any lectures intended to stimulate interest in science, and contacts with all existing groups likely to be interested should be established. The part which local societies may play in sustaining interest is to be noted. Both in propaganda lectures and in classes, demonstration experiments—which should, however, not be too numerous —have proved really useful features ' (D. M. Stewart, *Glasgow*).

Mr. G. C. Robson, British Museum (Natural History), believes there is not enough local publicity, and recommends that ' Local institutions and secretaries might do far more in the way of advertising courses and stimulating local societies to support them.' He further suggests that ' in view of the keen interest evident in the social implications of Biology, it might be fostered and developed if the potential teachers and lecturers (University graduates) were made aware of this demand. It is, perhaps, not sufficiently made apparent to a man during his University training that biology has a humanistic side. The acute specialisation must have the effect of withdrawing the average graduate from contact with popular needs and interests.'

8. *The Supply of Science Books, Equipment, and Materials.*

A. *Books.*

An adequate supply of science books is an important consideration in the equipment of a science class. The Committee have received several useful suggestions in reply to their inquiry in this direction. General library arrangements are very fully discussed in *Paper No.* 11 of the Board of Education Committee (p. 93–113). There is theoretically no limit to the facilities which exist for supplying the individual students with whatever books they require, through the co-operation of the County, or Borough Public Library scheme, the National Central Library, and the Extra-mural Libraries of the Universities. In practice, however, it depends very much upon the County or Borough authority concerned; in some districts a library regulation restricting the use of a book by a borrower to fourteen days prevents its use for class purposes; in other districts the Library Committee is distinct from the Education Committee, and there is some lack of co-operation. The fact that a class needs several copies of one book is another difficulty when the Public Library's stock is not sufficient.

In addition to the Public Libraries, many voluntary bodies, such as the Y.M.C.A. centres, possess fairly well-equipped libraries. The Working Men's College contains some 10,000 volumes. The University of London Library allows students to become borrowing members of the library, and also issues travelling libraries of the books needed during a course, for the special use of the class during the whole of its progress. Such travelling libraries are provided in connexion with all Tutorial Classes, and are sent to those University Extension Centres which apply for them.

The Education Library at County Hall has a science section upon which science teachers can draw.

The City Literary Institute Library is not supplied with textbooks, but possesses a fair supply of general scientific literature.

The following replies indicate some dissatisfaction with the type of book available:

'Many of the books recommended by tutors for students' reading are written mainly for the university undergraduate, and are unsuitable for adult students. There is little between these and the popular book on the wonders of the universe, which, while it may serve to stimulate interest, does not serve the needs of students. We need more books of the type of Dr. Firth's *Chemistry in the Home*, which was produced as a result of work done in this Department' (Prof. Peers, *Nottingham*).

'Lack of small "popular" books on elementary science—books which are not school textbooks but which are really readable—is a serious drawback. At present the Dorset County Library is not well supplied with such books; there is a lack of duplicate copies' (Resident Tutor, *Dorset*).

'There is an urgent need for science primers for adults' (Glasgow, W.E.A.).

In most districts the general arrangement for books seems to be satisfactory.

'There are a great number of popular science books available, and no difficulty has been experienced in finding suitable books for reading' (Dr. Chapman, *Sheffield*).

'Science books are at present provided by the University, through travelling libraries' (*Liverpool*).

'Books have generally been obtained from Burgh and County Libraries, the supply being supplemented where necessary from the Scottish Central

Library and from the resources of societies. A selection of books is placed at the disposal of the class throughout the class period, and this arrangement has proved very satisfactory ' (West of Scotland Joint Committee).

In the Adult School Union, special handbooks are published by the Union. These handbooks have a circulation of about 23,000 copies per annum, and the material is used as the basis for discussion throughout the whole Adult Schools in the country.

8B. *Equipment, Apparatus and Materials.*

References to equipment and to apparatus have been made under section 3C. The general situation appears to be that except for classes held in or near University or Technical Colleges the supply of apparatus and material is quite inadequate for lecture demonstrations, and still more so for class work of individual students. Hence many science classes have to depend upon lantern slides for the greater part of the work, with occasional help from films. Even in Oxford we are informed that ' it is seldom possible to have the use of a laboratory, or for members of a class to have access to one for practical work except during lecture hours.'

In Cambridge ' some Tutorial Classes (e.g. in Biology) have been able to meet in laboratories, but this depends on local circumstances (e.g. offer from a local school). In most cases a few microscopes have been supplied by the Extra-mural Board as part of the travelling library.' ' Two classes have been granted facilities by the University ; one has met for three years in the Biochemical Laboratory, and another for the same period in the Psychological Laboratory.'

In Manchester ' some material and equipment could be borrowed under guarantees from University departments. The laboratory accommodation in towns outside the University is the main difficulty.'

In Glasgow ' in some instances students have constructed their own equipment—one, for example, during a period of unemployment made an electrical machine to provide electricity to facilitate his experimental study of the subject. A nature study class gave an exhibition of collected specimens, and students habitually bring along specimens for discussion. Both University and Museum University departments are indebted to adult students for additions to their collections.'

In London from the point of view of the Local Education Authority, ' No difficulty appears to have arisen in the way of teachers and students finding such equipment and materials as are required for classes of the type under consideration. All the institutes are provided with lanterns and epidiascopes and the Council's magnificent collection of lantern slides is available for use by science as well as other lecturers. Many of the teachers have private equipment and in some instances are also able to draw upon resources provided by professional bodies and their daily occupations.'

From the point of view of one of the chief Literary Institutes in which science courses are taken and where there is practically no equipment for science teaching the position does not seem quite so simple. In one reply it is stated : ' With regard to classes in science conducted at the Institute, no public funds are expended on material, except for courses in Photography. Even here students themselves already supply a very considerable quantity of equipment and material. In general little consumable material is required, but whereas equipment such as microscopes, spectroscopes, and telescopes would be useful, one hesitates to press local Education Authorities to expend considerable sums for the provision of these, in view of the need for economy.'

Of all Institutions for adult classes, the Working Men's College seems to be best supplied with apparatus and material for science work. The equipment there seems to be quite adequate to the demand.

9. *Inter-communal Co-operation in the Science Work of Adult Classes.*

One of the most attractive and useful features of science work is the feeling it affords of a personal participation in the search for truth. In an attempt to obtain knowledge of things for oneself there is no limit to interest and enthusiasm. Even if it results only in gaining knowledge already known to other people, it is nevertheless research. Besides there are always new aspects of nature to be studied and when they are presented in the form of problems for investigation in which the student plays an active if not the principal part, science becomes a fascinating subject and a source of never failing interest.

This side of science work must not be overlooked in the future planning of science courses for adults; for this intrinsic interest of scientific research has a part here to play equally with the interpretation of scientific results in their application to modern life and social developments. One of the most fruitful methods of procedure is that of team work, wherein most or all of the students contribute, by their observations, towards a common objective, and thereby collect sufficient date in a comparatively short time to justify at least tentative conclusions almost impossible for the individual student to reach in the short time available. This is equally true where the results of field work and observations made by other groups of students in the same district can be pooled and utilised for wider generalisations. Useful survey work of a regional type may be undertaken by adult classes in subjects connected with agriculture, horticulture, flora, fauna, soil and climate of a district. Joint meetings should be organised for general discussions of results. Such an objective stimulates independent reading, serves as an incentive to continuous work, and broadens the outlook of the students.

Very little in the way of such interchange has hitherto been attempted, and little in the way of regional survey. This is probably because co-operative effort of this kind has not been considered possible. It is urged that inter-communal co-operation of the kind suggested would lead to more serious studies of the conditions affecting the welfare of the people, and assist in establishing a wider appreciation of the value of science to the community.

10. *Assistance from Local Scientific Societies to Adult Classes in their District.*

The active agents in promoting this inter-communal activity would naturally be a committee of lecturers and tutors of the district. Professor Julian Huxley suggests that 'local scientific societies should, possibly under advice from some central body, work out plans by which natural history, geological and survey work in the area could be profitably organised, and point out ways in which adult education classes and those interested could take part in such work.'

Similarly the Director of Extra-mural Studies in the University of Manchester suggests that 'it might be useful if the Extra-mural Departments of Universities, and the District Secretaries of the W.E.A. co-operated from time to time in calling local conferences of Field Clubs, Natural History Societies of various kinds, with a view to closer co-operation and

the development of facilities. Possibly some of the Societies would be willing to give practical assistance in this, and from time to time a one-day "School in Science" might be arranged through the hospitality of one or more such Societies. There has been a considerable revival of interest in Local History under the stimulus of the Rural Community Councils . . . perhaps in co-operation with these bodies a good deal might be done for geology, botany, and zoology studied locally. The Conferences arranged in Derbyshire and elsewhere have further stimulated interest and increased the knowledge of local history. The same thing might prove true if conferences of groups engaged in the study of natural history under local conditions were arranged in county or district areas.'

From the City Literary Institute, Mr. G. T. Williams sends similar suggestions. (1) Scientific societies might place their material occasionally at the disposal of classes, by means of travelling exhibits bearing on the work of particular groups which are conducting their studies in the Institutes. (2) Societies interested in promoting the study of some particular science, or aspect of science not usually comprised in the curriculum of Institutes, should formulate and circulate specimen syllabuses with reading lists, suggestions for equipment, and some indication as to method of approach. Institutes might be encouraged to offer in their programme classes which, without such suggestions, would ordinarily not have occurred to them as within the bounds of possibility. (3) Scientific societies that possess special equipment would allow groups from Institutes to meet for special demonstrations in their laboratories.

It is generally reported that Local Field Clubs and Scientific Societies are sympathetic and helpful. In Belfast 'classes are linked in an unorganised way with the local Naturalist Societies, i.e. many members of the classes pass to membership of these societies, and lectures attended thereat are often discussed in class.'

Many Committees for Adult Classes publish handbooks in which the programmes of the various scientific societies are included . . . as they realise that 'the help of local scientific societies in stimulating the demand for scientific study would be extremely valuable.'

The only district, according to the information supplied to the Committee, in which interchange of observations and the results of field work has been carried out, is in the Western (or Glasgow) District of Scotland. Here the Joint Secretary of the Extra-mural Education Committee reports that 'Contact has been maintained as far as possible between adult classes and local societies dealing with Astronomy and Natural History, to mutual advantage. The societies afford a field in which the adult students are able to carry further and to apply the knowledge gained by them in classes, while the classes afford to some of the members of the societies an opportunity of making their knowledge more systematic. . . . Nothing has been done yet in the way of interregional meetings of adult classes for comparison of local observations, but a beginning has been made with regional survey by adult classes, more particularly at Kilmarnock and at Dumbarton as part of the West of Scotland survey of plant and animal life, stimulated by the visits of the British Association. . . . It is hoped that from the nature study class at Dumbarton a local Natural History Society may develop. The astronomy section of the Paisley Philosophical Institution resumed meetings and activity after a long interval as a result of the contact of interested persons provided by an adult class.'

III.—Suggestions and Recommendations.

The Committee has not found it possible, during the current year, to deal with all the problems covered by its terms of reference. They have therefore decided to report in the first place on the 'position of science in Adult Education,' reserving for subsequent discussion the problems dealing with the improvement of the position of science, with the various modes of approach, with types of syllabuses, with the function of lecture courses, and of tutorial classes, and with other matters affecting the steps that ought to be taken for making science, not only a popular study, but a valuable and indispensable part of the education of an adult.

Suggestions to that end have been submitted to the committee by various correspondents, and several of these have already been quoted.

From the statements made to the Committee, it would appear then that, in general—

(1) The demand for science teaching among adults varies at present directly with the supply of competent teachers.

(2) The man is more important than the subject, and the subject than elaborate or expensive equipment.

(3) Apart altogether from systematic vocational training (which is outside the scope of this inquiry) the approach must be from popular everyday applications of scientific method on practical occasions and common experience, to the discovery of principles, and from such discoveries, in detail, to the formulation of a systematic body of knowledge. It is the scientific outlook, not a multiplicity of scientific experiences, that is to be achieved : as it has been expressed to the Committee 'you are not making science students ; you are preaching a gospel' ; and providing what has also been described as 'a useful adjunct to philosophy.'

(4) This difference of aim and procedure, between science teaching for adults, and systematic science-teaching in Universities, or even in schools, goes far to explain the dearth of teachers qualified to conduct this sort of course. For here the teacher's own systematic knowledge can only be applied effectively by reversing academic procedure, and guiding (or provoking) the process of rediscovery, and of generalisation from facts actually observed by the pupil or the class in some episode of daily life.

(5) While the historical approach to scientific problems provides, through its foundation in such experiences the most direct approach for adult classes, the prevalent neglect of the history of discovery among professional teachers of science is an important reason why teachers competent to teach science to adults are so rare.

(6) Much adult science, which hardly goes even so far as such rediscovery and generalisation, has nevertheless its value as a conscious contribution to learning, through regional observation, and is capable of enhancement, and refinement of technique, especially when it is pursued as team work, in conjunction with other workers.

(7) Here is the proper field of what was formerly called 'Natural History,' as an outdoor occupation primarily, though it presumes the leisured revision and comparison of the notes and collections of field workers, under the guidance of an experienced naturalist, who need not have academic or tutorial qualifications at all.

(8) This is where the adult class may reasonably appeal for help to the local Field Club or Natural History Society, and also to the local Museum. Both institutions stand to gain by enlargement of their range of field observers and voluntary collectors of regional material.

(9) The value of the work which is being done by certain voluntary and non-academic organisations should not be overlooked. More particularly the Women's Institutes in the country and the newly formed Townswomen's Guilds in the towns are bringing together large numbers of women unlikely to be touched by other bodies dealing with adult education. Up till now the instruction given in this connection has been mainly of practical character, but if lecturers with suitable outlook and interests were available much might be done through these organisations to stimulate an interest in achievement of science in relation to practical and social questions and to encourage a more scientific attitude of mind towards such matters.

IV. Select Bibliography of Science Teaching in Adult Education.

'Popularisation of Science through Public Lectures,' *Report* of British Association Committee (1916)

'Natural Science in Adult Education,' Board of Education Committee, *Paper No.* 8 (1927).

'Science and Adult Education,' *Conference Papers*, Oxford (1927), British Institute of Adult Education.

'Science, Industry and Human Life,' Sir John Sankey, *Conference Address*, Oxford (1927), British Institute of Adult Education.

Articles from the *Journal of Adult Education* :—

- 'Geology as a subject for Adult Classes,' by D. A. Allan, 1929.
- 'Some notes on Science and Adult Classes,' by M. I. Cole, 1930.
- 'The Need for the Popular Lecturer,' by A. Clow Ford, 1930.
- 'Physics and Adult Classes,' by G. Cochrane (1931).
- 'Astronomy for Adult Classes,' by T. L. Macdonald (1931).

The Social Function of Science, by Professor C. H. Desch, F.R.S. (1931), Sheffield University.

'Science in Adult Education,' by T. L. Macdonald. *The Tutor's Bulletin of Adult Education*, No. 2, 1931.

'Biology and the W.E.A.' by Dr. Norman Walker. *The Highway*, October 1932.

'Study of Science in Adult Classes,' *Report* of Executive Committee of Workers Educational Association (1932).

'Science and the Radio,' by Austin E. Clark. *Scientific Monthly* (1932).

'Memorandum on the W.E.A. Report on Science Study,' by Scottish Tutors, in No. 7, *Bulletin of the Association of Tutors in Adult Education*, 1933.

'A Tutorial Class in Physics,' by A. Cochrane, reprinted from the *Journal of Adult Education*, Vol. VI, No. 2, published by Sidgwick and Jackson, London, 1933.

V. Appendix.

The Committee wish to acknowledge their great indebtedness to all those who have been so good as to reply to the questionnaire and supplied memoranda which have formed the basis of this report. They desire to offer

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(1) The Board of Education.
(2) London University: Mr. John Lea, Extra-mural Department; Prof. Julian Huxley, King's College; Dr. A. J. Grove; Mr. G. C. Robson, British Museum (Natural History).
(3) London County Council, Education Department, Mr. G. H. Gater and Mr. E. M. Rich; City Literary Institute, Mr. G. T. Williams; Deptford Men's Institute, Mr. S. Myers; Bec Literary Institute, Mr. W. J. Gale.
(4) British Institute for Adult Education, Mr. J. W. Brown.
(5) Workers Educational Association, Mr. A. S. Firth.
(6) Y.M.C.A., Mr. A. Clifford Hall.
(7) Arsenal Co-operative Society.
(8) Working Men's College, Mr. C. Chapman.
(9) Morley College, Westminster, Mr. S. T. Cottrell; Mary Ward Settlement, Mr. Horace Fleming.
(10) Oxford University, Rev. F. E. Hutchinson, Extra-mural Department.
(11) Cambridge University: Mr. G. F. Hickson, Extra-mural Department; Mr. G. P. Bailey.
(12) Reading University, Dr. W. B. Brierley, Extra-mural Department.
(13) Bristol University: Mr. John Nicholson, Extra-mural Department; Mr. A. E. Douglas Smith, Resident Tutor, Wiltshire; Mr. W. R. Straker, Secretary, W.E.A., Western District; Mr. S. H. Can, Resident Tutor, Somerset; Miss M. R. Dacombe, Dorset.
(14) Midlands: Mr. L. A. Fenn, W.E.A., Birmingham; Loughborough College, Mr. R. J. Howrie, Extra-mural Department; Nottingham University College, Prof. R. Peers, Extra-mural Department.
(15) Sheffield University: Dr. A. W. Chapman, Extra-mural Department; Prof. C. H. Desch.
(16) Leeds University, Dr. Norman Walker, Extra-mural Department.
(17) Manchester University, Mr. H. P. Turner, Extra-mural Department.
(18) Liverpool University, Mr. E. Hickinbotham, Extra-mural Department.
(19) Durham University: Rev. E. G. Pace, Extra-mural Department; Mr. T. B. Tilley, Director of Education.
(20) Glasgow University: Mr. D. M. Stewart, Extra-mural Department; Mr. C. Cochrane; Mr. T. L. Macdonald, W.E.A.
(21) Belfast, Mr. H. J. Eason, Queen's University, Extra-mural Department.
(22) Women's Institutes, and The Townswomen's Guilds, Miss Masters.
(23) National Adult School Union, Mr. G. Peverett.
(24) American Association for Adult Education, Mr. Morse A. Cartwright.
(25) Kent, Mr. Salter Davies, Director of Education.
(26) Dr. Charles Singer.
(27) Sir H. Frank Heath, G.B.E., K.C.B., Universities Bureau of the British Empire.
(28) Lancashire, Mr. P. E. Meadon, Director of Education.

INLAND WATER SURVEY.

Report of Committee appointed to inquire into the position of Inland Water Survey in the British Isles, and the possible organisation and control of such a survey by central authority (*Original Members :* Vice-Adml. Sir H. P. Douglas, K.C.B., C.M.G., *Chairman* ; Lt.-Col. E. Gold, D.S.O., F.R.S., *Vice-Chairman* ; Capt. W. N. McClean, *Secretary* ; Mr. E. G. Bilham, Dr. Brysson Cunningham, Prof. C. B. Fawcett, Dr. A. Ferguson, Dr. Ezer Griffiths, F.R.S., Mr. W. T. Halcrow, Mr. C. C. Smith, Dr. L. Dudley Stamp, Brig. H. St. J. L. Winterbotham, C.M.G., D.S.O. *Co-opted Members :* Mr. T. Shirley Hawkins, O.B.E., Mr. W. J. M. Menzies, Mr. Henry Nimmo, Dr. A. Parker, Mr. D. Ronald, Capt. J. C. A. Roseveare, Dr. Bernard Smith, F.R.S., Mr. F. O. Stanford, O.B.E., Capt. J. G. Withycombe).

Contents of Report.

I. Introduction.

1. *Appointment of Committee and terms of reference.*—Following the meeting of the British Association held at York in September 1932, the General Committee, on the recommendation of Sections A (Mathematical and Physical Sciences), E (Geography), and G (Engineering), appointed a Research Committee for the following purpose :—

'To inquire into the position of Inland Water Survey in the British Isles, and the possible organisation and control of such a survey by central authority.'

A list of the members of the Committee so appointed is given at the head of this report.

2. *Appointments of Chairman and Sub-committees.*—The first meeting of the Committee was held on November 9, 1932, when Vice-Adml.

Sir H. P. Douglas was elected Chairman, Lt.-Col. E. Gold, Vice-Chairman, and Capt. W. N. McClean, Secretary. A number of additional members, whose experience in various branches of work connected with the subject would be of assistance to the Committee, were co-opted.

The Committee appointed two Sub-committees, viz. the Data Sub-committee to collect information relating to the first part of the reference, and the Schemes Sub-committee to investigate the second part. Their work is referred to below.

3. *Earlier demands for a survey.*—Demands and suggestions for a survey of the water resources of the country, and for a central water authority, have been made on many occasions in the past.[1] It is necessary, at the outset, to draw a clear distinction between an organisation for carrying out a water survey and a central authority or National Water Board for the administration and control of the national water resources. It is with the former only that this Committee is directly concerned. It is of interest to recall that the British Association identified itself with the earliest of these demands. In 1878, at a meeting of the Association in Dublin, a paper was read by Mr. J. Lucas, F.G.S., advocating a hydro-geological survey of England; and a discussion took place in the Mechanical Science Section at which Mr. Easton, the President of the Section, suggested the formation of watershed boards.[2]

In the same year, at a Congress of the Royal Society of Arts, a paper was read by Mr. C. Slagg in which the suggestion was made that a State record of the surplus water flowing from high and uncultivated lands should be regularly kept.[3] A paper was also read by Sir J. Clarke Hawkshaw, M.Inst.C.E.,[4] on the subject of 'River Conservancy.'

In 1902 the Salmon Fisheries Commission [5] expressed the opinion, identical with the suggestion made by Mr. Easton at the British Association Meeting in 1878, that the time had arrived when the Government should cause a survey and estimate of the water supplies available in all watersheds throughout the kingdom to be made for the use of the proposed watershed boards.

Before leaving the historical aspect of the subject, reference should also be made to the work of Mr. C. E. De Rance [6] in which he referred to a Research Committee appointed by the British Association in 1874 on the subject of the underground circulation of water, and to the above-mentioned Congress of the Royal Society of Arts. In this work, which may well be regarded as the forerunner of a water survey, the author describes the character and quantity of the existing water supplies, the area of the principal geological formations, with the amount of rainfall in each of the river basins delineated in the catchment basin map of the Ordnance Survey.

In more recent years the demand has been repeated, and instances, which, however, are by no means exhaustive, are quoted in Memorandum D (1); a few of the principal examples are briefly enumerated as follows:—

A Joint Select Committee of both Houses of Parliament, in 1910, expressed the opinion that there was need for a comprehensive survey of the water supply of the country.

In the same year Parliament ordered a Return as to water undertakings

[1] Forbes and Ashford, *Our Waterways*, chap. i. (Murray, 1906.)
[2] *Ann. Report*, B.A., 1878, pp. 689, 692. [3] *Report of Proc.*, 1878, p. 112.
[4] *Journal*, vol. 27, p. 623. [5] *Report*, pp. 12, 49–51, 61.
[6] C. E. De Rance, Assoc.Inst.C.E., F.G.S., *The Water Supply of England and Wales, its geology, underground circulation, surface distribution and statistics.* (E. Stanford, 1882.)

in England and Wales. This was compiled, and issued by the Local Government Board in 1914, as a first instalment of the comprehensive investigation which had been recommended by various Royal Commissions and Committees.

Subsequently, the Ministry of Health, the successors of the Local Government Board, appointed an Advisory Committee on Water who from time to time have issued various reports.

In 1921 a Committee of the Board of Trade on Water Power Resources issued their Final Report, which contains the results of extensive investigation as to the water power resources available for industrial purposes. The Committee recommended the establishment of a Water Commission (para. 32) whose primary function would be to compile a record of the water resources and water requirements of the country (para. 37).

In 1927 the Institution of Water Engineers in general meeting passed a resolution that there was urgent need of an organisation which would ensure a continuous record of the flow and storage of surface and underground water.

The passing of the Reservoirs (Safety Provisions) Act, 1930, and the establishment of Catchment Boards under the Land Drainage Act, 1930 (see Memorandum D (2) appended), have drawn attention anew to the subject as a matter of immediate urgency, particularly as regards the gauging of streams and rivers to provide reliable data on which to base estimates of flood flows; as instances of this may be quoted the Annual Report of the Ministry of Health, 1930–31 (pp. 14–15), and the draft Report of the Committee of the Institution of Civil Engineers on floods in relation to reservoir practice.

Finally, after the lapse of fifty-four years since the meeting at Dublin, the same demand has been repeated at the meeting of the British Association at York in 1932. The discussion, inaugurated by Capt. W. N. McClean, and supported by thirteen representative engineers and scientists, showed a unanimous opinion that the setting up of a national organisation for water survey was indispensable (*The Times*, September 7, 1932).

II. Position of Inland Water Survey.

4. *Scope of survey.*—Water conservancy has been defined by the President of the Mechanical Science Section of the British Association, at the Dublin Meeting in 1878,[7] as 'the treatment and regulation of all the water received in these islands from its first arrival in the shape of rain and dew to its final disappearance in the ocean.' This involves several branches of science:—

Meteorology, as regards the precipitation from the clouds, the primary source of all water supply, of rain, snow and hail; the condensation from the atmosphere of water in the form of dew or hoar frost; and as regards also evaporation by which a portion of the water is returned to the atmosphere. These, in their turn, are related to other meteorological factors, such as temperature and wind, and to geographical conditions, such as proximity to the sea or mountain masses;

Geology, as regards the absorption by the soil or rock of a portion of the water, its storage and flow in the underground strata and its return to the surface in the form of springs and seepage;

Topography, as regards the surface flow and storage of so much of the precipitated water as is neither evaporated nor absorbed. This includes

[7] *Report*, 1878, p. 679.

both the geographical conditions which affect the climate and the land surface conditions which determine the size and shape of catchment basins and the courses of streams and rivers.

It remains for the engineer engaged upon the control of water 'for the use and convenience of man' to give these sciences their practical application. It is for this purpose that he requires a quantitative survey, giving actual measurements of the volume of water available or to be discharged, as data for his schemes and designs.

The scope of a water survey necessary to meet these requirements of civil engineers and others interested in water conservancy should include observations and measurements and the preparation of continuous records in standard form, in connection with rainfall, surface storage and flow, and underground storage and flow—in conjunction, in each case, with the physical and geological characteristics of the area. The records from all sources should be collated, brought into harmony and made available.

5. *Existing organisations.*—The foundations of such a survey already exist, in part, in the work of well-established Government departments devoted to the special branches of science mentioned in the previous paragraph.

The published maps of the Ordnance Survey (Ministry of Agriculture and Fisheries) are so well known and appreciated that any description here is unnecessary.

The Geological Survey (Department of Scientific and Industrial Research) has made substantial contributions to our knowledge of underground water resources in its published maps and memoirs. The information thus collected is admittedly incomplete (see Memorandum E appended).

The British Rainfall Organization (Air Ministry), described in Memorandum C appended, having grown from small beginnings as a private enterprise until it was ultimately taken over by a Government department, provides the indispensable information as to rainfall on which engineers hitherto have had largely to depend for waterflow data.

There is, however, no such existing department or central organisation to deal with direct hydrological measurements of the amount of water derived from rainfall.

6. *Water users.*—The following table is a summary of the principal users of water with the purposes for which direct measurements of water are required in connection with their operations and the nature of the measurements and records thus involved.

Many of the bodies concerned, it is known, have measurements taken and recorded according to the needs of their particular interests and the special avocation of the engineer. In addition, certain scientific societies, including the Royal Geographical Society, and private undertakings, such as River Flow Records, have done much work on these lines. In some few cases, reports have been published (as the appended Bibliography indicates), but only a superficial knowledge of the subject can be gleaned from a study of these reports.

It may be anticipated that many will in due course extend this work. The consumption of water per head of population for domestic purposes has a steady tendency to increase, due to improved standards of sanitation such as the laying on of piped water supplies into houses in rural areas, the substitution of water-closets for privies, and the provision of baths and hot-water supplies. Thus the growth of population and the requirements of industry continually increase the demand on water supply resources throughout the country.

Memo. appended.	Users and Purposes.	Measurements and Records.
D (1)	*Surface Water Supplies for Domestic and Industrial Purposes.* Available reliable yield; droughts and floods; compensation water for riparian interests; and waste water.	Gaugings and levels of springs, streams, rivers, lakes and reservoirs; discharges and overflows.
D (2)	*Catchment Boards.* Land drainage; floods and flow control.	Ditto.
D (3)	*Hydro-electric Stations.* As (1) above, in relation to available water power for generating electricity.	Ditto.
D (4)	*Electricity Stations.* Feed and condensing water for steam plant; cooling water for oil- and gas-driven plant.	Ditto.
D (5)	*Canals and Canalised Rivers.* Navigational uses and losses by evaporation, leakage, etc.	Ditto.
D (6)	*Fishery and Pollution.* Fishery interests; pollution problems and dilution of sewage and trade effluents.	Ditto.
E	*Underground Water.* Available supplies from springs, wells and bores.	Gaugings of springs as (1) above; continuous or periodic water levels in wells and bores.

While the amount of water required is thus increasing, and large volumes run to waste, unused, to the ocean, the quantity available from suitable sources capable of maintaining the supply through times of drought is not inexhaustible. The most conveniently situated sources, whether of surface or underground water, have been to a large extent already appropriated, and it has long been recognised that a comprehensive survey of the national water resources is necessary to enable water conservancy to be placed on a basis of fact.

Again, with regard to rivers, it is said by an American author [8]: 'The damage from floods is increasing; occasioned more by the increased occupation of areas that are sometimes flooded than by any increase in the volume of flood flows.'

[8] A. Hazen, *Flood Flows.* (Wylie & Sons, 1930.)

'The land along any river may be divided into three parts :—

'(1) The river channel, which all agree ought not to be encroached upon.

'(2) The middle land, usually dry but sometimes flooded.

'(3) The high land above all floods.

'It is the increased occupation of the middle land that causes most of the trouble.'

This statement is largely applicable to this country, although conditions are different in many respects. Reliable data as to the volume of flood flows in past years are lacking in the case of all but one or two rivers. It is well known that river channels have been affected by artificial works, and that in many places houses have been built on land liable to occasional flooding. If any material alleviation is to be afforded to such areas by the River Catchment Boards a thorough study of the river flows is a first essential.

7. *Absence of co-ordination.*—The foregoing gives a general indication of the diversity of interests concerned with water conservancy in some form. Numerically there are believed to be, in round figures, over 800 local authorities and joint boards for water supply ; some 300 water companies and over 1,000 private proprietors ; 46 catchment boards at present established ; and over 500 electricity stations, in addition to canal authorities, pollution boards, fishery boards and hydro-electric undertakings. Private interests, such as mills and riparian owners generally, are innumerable.

As has been mentioned, some of these bodies take gaugings and measurements and keep records for their own purposes, but, so far as it has been possible to ascertain, these form a small minority, and in general there is an entire absence of co-ordination or of any organisation for systematic recording of data.

III. Possible Organisation and Control of an Inland Water Survey by Central Authority.

8. *Examples of organisations in other countries.*—National water survey organisations have been in existence in many countries for a number of years. The practice abroad, so far as is exemplified in that of four representative countries reviewed in Memorandum B of this Report, is, however, by no means uniform. In three out of four cases the observation of rainfall is the function of a meteorological survey which is not only separate and distinct from that of stream and water storage measurements, but is itself the subject of diverse arrangement ; in Italy alone, with a very recent organisation on national lines, is the whole series of duties combined in a single service—the Servizio Idrografico Italiano. In Canada meteorological observations are associated with and controlled by the Department of Marine ; in the United States the Weather Bureau is attached to the Department of Agriculture, while in Switzerland there is a Station Centrale de Météorologie, or Meteorologische Zentralanstalt. Stream measurements and gauging are undertaken in Canada by the Dominion Water Power and Hydrometric Bureau, which is a branch of the Department of the Interior. In the United States the duties are undertaken by the Geological Survey, similarly a branch of the Department of the Interior, as one of a group of activities carried on by five co-ordinate branches. In addition to this, measurements of river levels are made in certain cases by the Weather Bureau, which also issues flood warnings. In Switzerland there is a special Service des Eaux (Amt für Wasserwirtschaft) which devotes itself entirely to hydrometry and the economics of water development.

Particulars of the services in other countries might be cited,[9] but the foregoing instances suffice to show the diversity of the systems in vogue on the Continent of Europe and in North America.

9. *Systems of measurement.*—As described in para. 8, above, the authorities in other countries have adopted the direct method of measuring the flow itself and obtaining positive data for the study of such subjects as flood flows, their frequencies and magnitudes.

In this country, however, the collection of rainfall statistics has been highly organised, but the direct method of measuring the flow has not been widely developed, with the result that the engineer who requires to know the yield of the rainfall, whether the quantity of water available or the maximum flood flow, is usually left in the position that he must make an approximate estimation of this by empirical formulæ based upon the rainfall.

It thus arises that, while engineers in other countries have at their command a store of data extending over many years for a scientific analysis of the subject, committees of British engineers, engaged upon the consideration of such important subjects as the assessment of compensation water and floods in relation to reservoir practice, have had to confess themselves hampered by an insufficiency of such data ; and the engineers of catchment boards responsible for the control of rivers, to whom measurements of the river flow over a series of years are of primary importance, have, in many cases, to begin taking river gaugings practically *de novo*.

10. *Ideal to be aimed at for this country.*—The organisation of a survey for the purpose of providing hydrometric data in connection with water conservancy must be considered in its broader aspects in relation to the general conditions and requirements of the particular country concerned. The various systems adopted in other countries have been referred to as affording some useful guidance from their example and experience rather than to enable a model which can be copied to be selected. The conditions differ very materially ; for instance, irrigation, which is vital in some countries, is of minor importance in Great Britain ; hydro-electric development is a necessity in many countries and is of increasing importance here ; floods on British rivers do not compare in magnitude with those experienced in some parts of America ; and in many cases there remain in those countries very extensive water resources as yet undeveloped.

In Great Britain, on the other hand, the predominant interest is the ever-increasing need of public water supply for domestic and trade purposes, while, to a very large extent, the more economically available and accessible sources have already been appropriated and developed. Second only to this in importance are the problems of drainage, floods, motive power, navigation and fishing.

Though the organisations of other countries, therefore, do not afford a model, their experience, particularly that of the United States, points to two important principles : (*a*) that the investigational activities of a survey should be segregated from those related to construction and administration ; and (*b*) that continuous and reliable records can be collected only by the State ; ' those collected by other agencies, however meritorious and serviceable in themselves, will be liable to lack of continuity, will not be generally available to the public, and will be open to suspicion as to reliability.' [10]

If these principles be accepted, as in the opinion of the Committee they should, it necessarily follows that the organisation of a water survey should be a national undertaking. The ideal to be aimed at for Great Britain, therefore, is a Government department (or section of a department) working

[9] *Trans. of First World Power Conference*, vol. i. [10] See Memorandum B.

as a central hydrometric authority in the closest co-operation with the Rainfall Organisation and the Geological and Ordnance Surveys, and independent of any interest concerned with the use or control of water.

This ideal implies that the authority, conducting a scientific research for the benefit of the community, should be financed by public funds and provided with necessary powers. The Committee consider that this should not prove to be an impossibility in view of the very different attitude now adopted by the Government towards scientific research compared with that of fifty years ago, provided the need is made sufficiently clear and the demand adequately supported by those directly concerned.

11. *Review of available data.*—With a view to exploring this position the Sub-committee appointed to collect data has obtained a number of memoranda from members of the Committee and others representative of the various interests. These are annexed as an Appendix to this Report.

A.—The bibliography indicates the very diverse sources which have to be consulted in order to obtain the limited amount of information on the subject at present published.

B.—Contains brief particulars of the organisations for water survey in the United States of America, the Dominion of Canada, Switzerland and Italy.

C.—Describes the existing organisation and the work of the British Rainfall Organisation. *Sub-memorandum :—*

> *C* (1).—Describes the rainfall information needed in relation to inland water survey and the arrangements necessary to obtain the data.

D.—Deals generally with the problem of water survey as regards surface water ; the routine of the necessary measurements and observational work, and its application to the various water interests. *Sub-memoranda :—*

> *D* (1).—Summarises the present position in regard to public water supplies in England and Wales, and is supplemented by D (1) (*a*) in regard to the records of water supply authorities.
>
> *D* (2) and *D* (2) (*a*).—Give a detailed account of the catchment boards recently established, and are supplemented by D (2) (*b*), (*c*) and (*d*), which describe the gaugings taken in three typical instances.
>
> *D* (2) (*e*).—Describes the work as regards river gauging of a typical rivers board dealing with pollution.
>
> *D* (2) (*f*).—Describes the interest taken in the subject by the Motor Boat Association, representing the views of the owners of motor boats who use the rivers for pleasure purposes.
>
> *D* (3).—Indicates the water records kept by hydro-electric companies and points out the importance to them of long-period records of river flow.
>
> *D* (4).—Explains the water requirements of the generating stations of authorised electricity undertakings, and is supplemented by D (4) (*a*) and (*b*), giving particulars of the gaugings in two typical instances, and by a schedule of the flow of some fifty rivers.
>
> *D* (5).—Describes the water requirements generally with regard to canals and navigable rivers.
>
> *D* (6).—Deals with the question of river gauging in relation to water pollution from the point of view of river boards and fishery boards.

E.—Contains suggestions as to observations and measurements necessary in regard to underground water, and describes the work of the Geological

Survey in connection with water supplies. It is supplemented by E (*a*), (*b*), (*c*) and (*d*), which give particulars in respect of four typical underground sources.

F.—Describes generally the operations of river gauging and is supplemented by two typical instances in F (*a*) and (*b*).

These memoranda cover a wide field and are representative of the more important interests directly concerned with water conservancy, and generally they may be said to indicate the need and utility of a survey.

IV. Conclusions and Recommendations.

12. *Conclusions.*—The conclusions at which the Committee have arrived as a result of their investigations are :

(i) That, with regard to the first part of the Committee's reference, the position of inland water survey in the British Isles is far from satisfactory and that a systematic survey of the water resources of Great Britain is urgently required ; and

(ii) That, with regard to the second part of the Committee's reference, the survey, to be of maximum utility, should be conducted by a central organisation, preferably under a Government department, independent of any interest in the administration, control or use of water.

The Committee have further given consideration to the steps by which the work of the survey could be most expeditiously begun. They have formed the opinion that it would not be feasible in the first instance, under present conditions, to move for the immediate establishment of an organisation to be financed by public funds, but rather that a beginning should be made in a comparatively small way, financed by subscriptions from individuals and bodies interested, with the prospect of being ultimately incorporated in a Government department.

With this in view the Committee have approached the Council of the Institution of Civil Engineers and have been gratified to learn that the Council will be prepared, if they are so requested by the British Association, to appoint a Committee to investigate the feasibility of carrying out the objects outlined in this Report on a self-supporting basis.

13. *Recommendations.*—

* * * *

In submitting this Report the Committee desire to place on record their high appreciation of the services rendered by Capt. W. N. McClean, the Hon Secretary.

APPENDIX: MEMORANDA.

INDEX.

MAIN MEMORANDUM *A*.

BIBLIOGRAPHY OF THE MORE IMPORTANT PAPERS DEALING WITH INLAND WATER IN THE BRITISH ISLES.

1. GENERAL.

(a) *Return as to Water Undertakings in England and Wales*, published by the Local Government Board, 1914.

This publication of 642 pages gives details as to every water undertaking in England and Wales, with particulars as to the various sources of supply

in each case, whether from lakes, rivers or streams, upland surfaces, springs or underground sources.

(b) *The Final Report of the Water Power Resources Committee*, 1921.

A summary of the report is given in pp. 72–86. Appendix L (p. 146 onwards) contains details of a system by which the compilation of records can be effected.

(c) *The Final Report of the Water Power Committee of the Conjoint Board of Scientific Societies.*

(d) 'Report on Stream Flow and Underground Water Records,' *Trans. Inst. Water Eng.*, vol. xxxiv, 1929.

(e) *Annual Reports of the Water Pollution Research Board of the Department of Scientific and Industrial Research.*

Recent reports have stressed the importance of systematic records of river flow in considering problems of the disposal of sewage and trade effluents.

(f) *Ministry of Health Advisory Committee on Water. Report of the Technical Sub-committee on the Assessment of Compensation Water*, 1930.

The conclusions set forth in the report are based on records from a number of catchment areas, which are not available to the general public.

Some comments on this report are given in the *Report of the British Waterworks Association*, 1930.

(g) *Water Pollution Research. Technical Paper No. 2 : Survey of the River Tees. Part I : Hydrographical*, published by the Department of Scientific and Industrial Research, 1931.

This report gives the results of measurements of current flows in the tidal estuary of the river Tees during 1929. It also includes measurements of freshwater flow at different levels. These measurements were made in surveying the river Tees in connection with pollution problems. Additional measurements were continued until about June 1932, and it is expected that these will be included in a Final Report of the Survey, to be published during the next year or two. The measurements have not included *continuous* records of water level.

(h) *British Waterworks Year Book and Directory*, with statistical tables, published by the British Waterworks Association.

The third edition, for 1930–31, contains useful information respecting 871 water undertakings. The information deals with such subjects as sources of supply, filtration, distribution, hardness of the water, total quantity supplied and estimated population.

2. The Measurement of Stream Flow.

(a) *Report on Current Meters for use in River Gauging*, 1922.

(b) *Report on River Gauging (dealing with methods and appliances suitable for use in Great Britain)*, 1925.

These two reports were prepared by M. A. Hogan for the Committee on Gauging Rivers and Tidal Currents, of the Department of Scientific and Industrial Research. The former deals with the information available as to the conditions affecting the design and use of current meters, and gives a description of those types in use.

(c) *The Gauging of Rivers*, statement on pp. 14 and 15 of the 12th Annual Report of the Ministry of Health, 1930–31.

This statement in reference to the more systematic gauging of rivers and underground waters is based on the work of a Committee set up by the Minister of Health to consider the subject and to act as a Sub-committee of the Ministry's Advisory Committee on Water.

3. Records of Stream Flow.

(a) *The Investigation of Rivers*, Final Report, by A. Strahan, N. F. Mackenzie, H. R. Mill, and J. S. Owens (published by the Royal Geographical Society, 1916).

This report and the four interim reports, published from 1908 to 1911, deal with the discharges of the rivers Severn, Exe, Culm, Creedy and Medway, and contain a report on the rainfall of the Exe Valley.

(b) *Monthly Reports of the Thames Conservancy.*

These give daily values of the natural flow and rainfall over the Thames Valley above Teddington Weir. The *Annual Reports of the Metropolitan Water Board*, published since 1903, give monthly totals as above.

(c) 'Gauging and Recording the Flow of Streams,' by S. C. Chapman. *Trans. Inst. Water Eng.*, vol. xv, 1910, p. 147.

(d) 'The Yield of Various Catchment Areas in Scotland,' by W. C. Reid. *Proc. Inst. Civil Eng.*, 1913. Paper No. 4048.

(e) 'The Measurement of the Flow of the River Derwent, Derbyshire,' by E. Sandeman. *Proc. Inst. Civil Eng.*, 1913. Paper No. 4056.

(f) 'Investigations into the Flow of the River Dee,' by C. H. Roberts. *Trans. Inst. Water Eng.*, vol. xxiv, 1919, p. 60.

(g) 'Notes upon the Average Volume of Flow from Large Catchment Areas in Ireland; the probable duration of stated rates of flow, etc., deduced from gaugings on the River Shannon at Killalow,' by J. Chaloner Smith. *Proc. Inst. Civil Eng.*, Ireland, January 1919.

(h) *Annual Reports of the West Riding of Yorkshire Rivers Board.*

Some data relating to the flow of rivers have been given in these reports, e.g. in that on the river Don, issued in 1923 (*Special Report No.* 155).

(i) *Quarterly Reports of River Flow Records, Ness Basin, Rivers Garry and Moriston*, 1929–31, by W. N. McClean.

Continuous records of water level are kept at seven or eight principal points on the Ness Basin of 700 square miles, and the flows of the rivers Garry, Moriston and Ness have been measured for all water levels between ordinary low water and ordinary flood level. The reports give daily comparison of rainfall, water level and flow. The records are being maintained and are prepared for publication when the opportunity occurs.

A paper on this subject by W. N. McClean was published in the *Geographical Journal*, vol. lxxvi, 1930, No. 1, pp. 39–49.

(j) 'The Lochaber Water-Power Scheme,' by W. T. Halcrow. *Proc. Inst. Civil Eng.*, 1931. Paper No. 4796.

4. Lakes and Reservoirs.

(a) 'Bathymetrical Survey of the Fresh-Water Lochs of Scotland,' by Sir John Murray. *Geographical Journal*, vols. iv, ix, xv–xviii, xxii–xxviii, xxx, xxxi, and xxxvi.

(b) 'The English Lakes, with Bathymetrical Maps and Illustrations,' by H. R. Mill. *Geographical Journal*, July and August 1895.

(c) Some statistics as to storage capacities of the various water undertakings are given in the Section on Waterworks Statistics in the *Water Engineers' Handbook and Directory*, 1932, and in the *Return as to Water Undertakings in England and Wales*, published by the Local Government Board, 1914 (see 1, a).

5. Flood Levels.

(a) ' Floods in England and Wales, 1875,' by G. J. Symons. *Proc. Inst. Civil Eng.*, 1876. Paper No. 1464.

(b) ' Floods of May, 1886,' by W. Marriott and F. Gaster. *Q.J.R. Meteor. Soc.*, vol. xii, 1886, pp. 269–282.

(c) ' Floods in the West Midlands,' by Henry Southall. *Q.J.R. Meteor. Soc.*, vol. xxi, 1895, pp. 28–39.

(d) ' November Floods of 1894 in the Thames Valley,' by G. J. Symons and G. Chatterton. *Q.J.R. Meteor. Soc.*, vol. xxi, 1895, pp. 189–206.

These papers give details of the heights attained by certain rivers during floods, which can be taken as typical of the information of this character available.

(e) ' Report on Thames Floods,' by A. T. Doodson, and the ' Meteorological Conditions associated with High Tides in the Thames,' by J. S. Dines, published by the Meteorological Office, *Geophysical Memoir No.* 47, 1929.

An investigation carried out after the disastrous floods in the Thames, January 6–7, 1928, as to the causes of such floods.

6. Land Drainage.

(a) *The Land Drainage Act*, 1930.

Part II, section 5, provides for the preparation of maps of catchment areas. In certain cases these have already been prepared, under Capt. Withycombe, by the Ordnance Survey.

Part V, section 43, p. 41, refers to ' powers of Drainage Boards to enter and survey lands.'

(b) ' Land Drainage in England and Wales,' by J. C. A. Roseveare. *Trans. Inst. Water Eng.*, vol. xxxvii, 1932.

(c) ' Present Conditions of Arterial Drainage in some English Rivers,' by R. F. Grantham. *Proc. Inst. Civil Eng.*, 1916. Paper No. 4184.

7. Underground Water.

(a) *Water Supply Memoirs* and publications on *Wells and Springs* of certain counties, published by the Geological Survey of Great Britain. These give records of sinkings and borings ; each volume, dealing with a particular county, includes a detailed bibliography.

The *Water Supply Memoirs* include those of Berkshire and Oxon., Bucks and Herts, Essex, Hampshire, Kent, Nottingham and Lincolnshire, London Wells, Bedfordshire and Northamptonshire, Norfolk, Suffolk, Surrey, Sussex, Yorkshire (E.R.), Cambridge, Huntingdon and Rutland ; and Memoirs on *Wells and Springs* of Somerset, Sussex, Leicester, Derby and Dorset have already been published.

(b) Various papers published in scientific and technical journals, including especially the publications mentioned on pp. 415, 420, and 421 of this Report.

8. Rainfall.

A short bibliography of papers relating to the rainfall of the British Isles is attached to the Memorandum on the British Rainfall Organization.

MAIN MEMORANDUM *B*.

ORGANISATIONS IN CERTAIN FOREIGN COUNTRIES.

By BRYSSON CUNNINGHAM.

The following particulars of organisations of water survey in foreign countries are derived from information which has been courteously supplied from official sources in response to inquiries.

I. UNITED STATES OF AMERICA.

The collection of basic information on water, its quantity, quality and utility, is made in the United States by two Federal bureaus : the Weather Bureau and the Geological Survey. The Weather Bureau collects information with respect to meteorological phenomena, including rainfall, snowfall, temperature, wind movement, etc., and also obtains records of stages and makes flood predictions for certain of the rivers which have sufficient length to permit of the forecasting of floods a considerable time in advance of their actual occurrence. The Geological Survey collects information on the quantity, chemical quality, availability and utility of water, both surface and underground, with reference to its control by reservoirs or levees, and to its utilisation for various purposes.

Administratively, the Geological Survey is grouped with other bureaus in the Department of the Interior, and consists of five co-ordinate branches : the Geologic Branch, the Topographic Branch, the Alaskan Branch, the Conservation Branch, and the Water Resources Branch.

The Water Resources Branch, which is primarily concerned with the collection of data relating to water, is, in turn, made up of five divisions : Division of Surface Water, Division of Ground Water, Division of Quality of Water, Division of Power Resources, and Division of Water Utilisation. The Water Resources Branch maintains at the present time 2,900 river gauging stations, of which about 2,000 are equipped with recording gauges.

Records of systematic observations in meteorology are published by the Weather Bureau. Similar observations in regard to water, both surface and underground, are published by the Geological Survey.

The cost of collecting the data and maintaining the above services is divided between the Federal Government and the several States. The Geological Survey conducts the major part of its investigational work in regard to water supplies in co-ordination with about 40 out of 48 States. This co-operative work is paid for jointly, but is supervised and controlled by the Geological Survey.

The Director of the Geological Survey, who furnished the foregoing information, makes a striking comment which must be quoted in full :—

' One of the phases of our organisation, which may be of sufficient interest to justify me in mentioning it specifically to you, is the segregation of the investigational activities from those related to construction or administration. This segregation seems to us in this country to be of considerable importance because of the human tendency to protect in times of stress only those activities that are of greatest interest to the controlling officials, and because of the suspicion as to integrity or reliability of records that arises if the responsible agency in their collection has *ex parte* interests in the records.

' It has been, I believe, well demonstrated here that continuous and reliable records needed as a basis for sound development or for satisfactory

administration and adjudication can be collected only by the States or the Nation. Records collected by other agencies will be liable to lack of continuity, will not be generally available to the public, and will be open to suspicion as to reliability.'

Finally, it is to be noted that boundaries of districts in which the field work of the Surface Water Division is carried on, are made along State lines in order to simplify arrangements for State co-operation. In general, each district covers an area of one or more States.

II. Dominion of Canada.

Observation of rainfall in Canada is the function of the Meteorological Service of Canada, which is a branch of the Department of Marine. The Service maintains over 700 climatological and other stations making continuous records of pressure, humidity, cloudiness, wind, precipitation and evaporation. Records are published monthly, and information is supplied free of charge.

The measurement and recording of stream flow is undertaken by the Dominion Water Power and Hydrometric Bureau, which is a branch of the Department of the Interior and is carried on in each province by virtue of co-operative agreements between the Department and the respective provincial governments, under which the Department is responsible for the basic investigations with the requisite staff and equipment, while the provinces contribute to the cost of the field work but not on a uniform basis. The organisation has been developed over a period of years dating back to the end of last century, when stream measurement work was begun in Alberta in 1898. The scope of the hydrometric survey now includes every province in the Dominion, and the Bureau obtains and publishes all essential data on basic problems relating to stream regulation, flood control, navigation, water-power, irrigation, drainage, municipal water supply and other uses of water. The number of gauging stations throughout the Dominion at present in use is 451 : others, having served their purposes, are discontinued. Many discharge measurements are made at points where no regular gauging station is established. There is a flood warning service to those districts where serious floods are liable to occur.

Storage reservoirs to control stream flow have been constructed in many parts of Canada, principally to secure a regulated flow for water power development ; these structures have been mainly the result of private enterprise, but some have been built by the Dominion and provincial governments for various purposes. The policy of governmental assistance to water power development has been carried out on a large scale in the province of Quebec under the direction of the Quebec Streams Commission.

III. Switzerland.

In Switzerland there are two independent organisations concerned with the collection of data relating to water. Rainfall and meteorological observations come under the jurisdiction of a Central Station of Meteorology at Zurich, while the collection of hydrometric data and the supervision of hydraulic development throughout the country fall within the domain of the Federal Water Service (Service fédéral des Eaux).

Hydrometric observations include the levels of water in the lakes and important watercourses, estimation of discharges, the taking of profiles along and across certain watercourses, the soundings of lakes at certain points—in front of their outlets and of deltas, for example—the contouring of basins emptying into watercourses, etc.

For the observation of water levels there are about 300 stations on different watercourses and lakes, and the levels are read from one to three times a day by observers who receive a modest remuneration. More than half of the stations are provided in addition with automatic apparatus for recording the levels graphically. These observations are reported according to their importance every day, every week, or every month. The most important stations only are permanent; secondary stations are abandoned when observations have been taken for a sufficiently long period, generally from ten to fifteen years, and the apparatus removed to a fresh position. As regards hydraulic development, the Federal Water Service has supreme supervision over the utilisation of hydraulic power from all watercourses, public or private, and to this end they examine projects of hydraulic electric developments on the basis of a rational utilisation of the force as a whole. They investigate also cognate questions such as the regularisation of the flow from natural lakes, the creation of storage basins, the steps to be taken for reserving the exercise of river navigation, etc.

IV. Italy.

The present Italian Hydrographic Service (Servizio Idrografico Italiano) is of recent formation, having been instituted at the close of the Great War, though it was preceded by two important regional bodies, the Hydrographic Office of the Royal Magistracy of Waters, located at Venice, and the Hydrographic Office of the Po, at Parma. In 1917 there were added to these two northern districts eight other regions throughout the country, and in 1923 the Italian Government placed them all under a central authority at Rome—the Third Section of the Consiglio Superiore dei Lavori Pubblici.

The functions of the Service are twofold, comprising duties of a permanent character and special research work.

The permanent duties comprise :—

(*a*) Meteorological observations, including temperature and rainfall.

(*b*) Observations and measurements of surface water, covering levels of watercourses and lakes, the discharge of watercourses, the amount of sediment in suspension, the temperature of watercourses and lakes.

(*c*) Observations and measurements of subterranean water.

(*d*) The periodical publication in the *Hydraulic Annual* of the results of the above observations and measurements; and

(*e*) Collaboration with the Department of Civil Engineering in developing water utilisation concessions and in investigating important schemes of hydraulic works.

The hydrometrical organisation at the end of 1930 had a total of 1,199 observation posts, of which 748 were hydrometric stations and 451 stations for measuring discharges.

Main Memorandum *C*.

THE BRITISH RAINFALL ORGANIZATION.

By E. G. Bilham.

The Organisation was founded about 1860 by G. J. Symons, and remained a private enterprise until 1919, when the accumulated records were acquired by H.M. Government, and the Meteorological Office, Air Ministry, assumed responsibility for continuing the work. The agreement under which the

transfer was effected provided for the annual publication of *British Rainfall* in the same form as in the past, and for the continuance of other work done by the Organization 'in like manner.' This agreement has been scrupulously observed, with the result that cordial relationships have been maintained with the band of voluntary observers, and with engineers and others who were accustomed to look to the Organization for guidance in questions relating to the supply and interpretation of rainfall data.

At the time of the transfer the Organization was rightly described by the retiring Director, Dr. H. R. Mill, as 'having no parallel in any country.'

Outline of the Organization.

In its present form the Organization forms a section of the British Climatology Division of the Meteorological Office, an arrangement which ensures that the resources of the Organization may benefit to the fullest extent from the large amount of rainfall data included in the climatological returns rendered to the Meteorological Office by voluntary and official stations. The Meteorological Office has been since 1919 attached to the Air Ministry, and its general policy is guided by a Committee, the Meteorological Committee, appointed by the Air Council, on which the Royal Society, the Royal Society of Edinburgh and various Government departments are represented. Full details will be found in the *Report* of the Meteorological Committee for 1920.

The aim of the Organization is to encourage private persons and local authorities to supplement the work of paid Meteorological Office observers by making reliable observations of rainfall, to preserve such records for public use, and to publish the data as fully as possible in the annual volume *British Rainfall*. In pursuance of this object the Organization is at pains to get into touch with all persons who are known to possess rain-gauges and to invite them to forward a copy of their readings at the end of each year on a register (Form 1090 for inch measurements, Form 1091 for millimetre measurements) supplied gratis. A pamphlet, 'Rules for Rainfall Observers,' originally drawn up by G. J. Symons, sets out the approved procedure for measuring rainfall and gives advice on the selection of a site and the type of gauge to purchase. This is sent gratis to observers, actual or prospective.

The *Observing Stations* fall into a few well-defined categories :—

	Approximate Numbers
(1) Official Meteorological Office stations—i.e. stations where the observers are whole-time or part-time employees of the Meteorological Office	50
(2) Climatological stations—i.e. stations where rainfall is measured as part of the routine of general climatological work	300
(3) Stations maintained by public authorities (mainly water engineers) or companies concerned with water supply or water power	1,000
(4) Stations maintained by other authorities, mainly private persons	4,000

The observers in category (1) are paid for their observations and returns by the Air Ministry. In a few other cases where a voluntary observer is not available a small annual payment is made for observations of rainfall, and in a few additional cases the observer takes readings without payment

from a gauge lent by the Office. With these few exceptions the Organization relies for its data on returns made voluntarily by persons who have purchased instruments themselves.

In general, daily readings of rainfall are furnished by all observers, but for many stations in remote parts of mountains or moors only the monthly total is available. All stations in categories (1) and (2) and selected stations in other categories forward monthly reports of daily rainfall, for use in drawing the rainfall map published in the *Monthly Weather Report.* At the present time the number of stations reporting monthly is about 1,400. For about 600 of these stations the monthly total is printed either in the *Monthly Weather Report* or the *Meteorological Magazine*, and for a large proportion of these the percentage of or difference from average is also given. The remaining stations render an annual return only.

Most stations in category (1) and a few in other categories maintain recording gauges, from the records of which data in regard to rainfall duration and the intensity in heavy falls are evaluated. Eighty-one such records were available in 1931.

Local Rainfall Organisations.

In many parts of the kingdom local interest in rainfall is fostered by organisations, often forming a part of a local scientific society, which collect observations from their correspondents and publish the readings in various forms, usually in the newspaper Press. These organisations have no official status, but they represent some approach to a regional system of dealing with rainfall data. They vary much in regard to the scale of their activities. At one end of the scale we have an organisation in Ayrshire under the control of Mr. W. Dunbar of Kilmarnock, who publishes shortly after the close of each month a duplicated report containing readings for 100 stations, together with a map showing the distribution of rainfall over the area. At the other end of the scale would be a small group of observers sending in records once a month to a secretary for insertion in the local paper. In some cases it is found possible to utilise the services of the local organiser to deal with questions of the exposure of gauges and reliability of readings, but such services are not utilised in any general or systematic way. A list of local organisations known to the British Rainfall Organization is appended :—

Hertfordshire Natural History Society and Field Club (Mr. C. P. Sinclair).
Northamptonshire Natural History Society (Mr. R. H. Primavesi).
Norfolk Rainfall Organisation (Col. H. C. Copeman).
Barnstaple Athenæum (Miss Young).
Mid-Wessex Rainfall Association (Rev. F. P. Synge).
Cornwall Rainfall Association (Mr. A. P. Jenkin).
Manchester and Stockport Rainfall Organisation (Mr. A. A. Barnes).
Irish Rainfall Association (Mr. E. W. M. Murphy).

Mr. A. J. Jenkins of Jersey, Miss Cordelia Marshall of Ambleside, and Mr. W. Dunbar of Kilmarnock also collect rainfall statistics regularly.

Extraction, Charting and Publication of Data.

Monthly and annual totals for nearly all stations are plotted on maps, from which the charts of rainfall distribution published in *British Rainfall* on a greatly reduced scale are drawn. Maps are also prepared showing the annual number of ' rain-days ' and ' wet-days.' The monthly and annual total fall for every station is entered on a ' ten-year sheet.' Stations

are classified geographically, first by Districts (groups of counties), then by River Divisions. Ten-year sheets for stations in the same River Division are filed in sequence, the file thus forming, when completed, a ten-year history of the rainfall in each River Division of a District. This arrangement makes it possible readily to turn up the rainfall at any station in any month and year.

For the great majority of stations the space allotted in *British Rainfall* is a line in Part III giving the diameter of the gauge, the height of its rim above ground, the height above sea-level, the average rainfall (if known), the year's total, the number of rain-days and the number of wet-days. Such data were published for 5,329 stations in 1931, 5,316 in 1930, and 5,180 in 1929. The number has been in the neighbourhood of 5,000 for the past twenty years. Unfortunately the distribution of stations is very uneven, the sparsely populated districts being poorly represented. The number of records per 100 square miles of area is as high as 28 in Middlesex, but is under 1 in parts of Scotland and Ireland. About 300 new stations are enrolled every year, and about the same number terminate. The average ' life ' of a station is therefore about eighteen years. A frequent cause of the cessation of a record is the death of the observer or his removal to a new district. In some cases it is possible to arrange for the record to be continued by a relative or the new resident, and every effort is made to ensure such continuity, more particularly in the case of long records.

The records for all stations are scrutinised in relation to ' heavy falls on rainfall days ' (*British Rainfall*, Part II, Section 7), but selections of stations are made for the purpose of studying the special aspects of rainfall dealt with in other sections of the volume. For example, 100 stations are used for the purpose of Part II, Section 2 (number of rain-days and wet-days), Section 3 (droughts), and Section 4 (rain-spells), 400 stations for Section 8 (monthly rainfall, Table XX), and 150 stations for Tables XXI and XXII, giving the monthly and seasonal fall as a percentage of the average.

Rainfall Data in other Publications.

Reference has already been made to the *Monthly Weather Report* and the *Meteorological Magazine*. Other Meteorological Office publications containing rainfall data are the following :—

The *Weekly Weather Report* gives weekly and seasonal totals of rainfall at each of sixty stations, together with the heaviest fall in each week and the relation of the weekly total to the normal. General values [11] for Districts are also given.

The *Observatories Year Book* contains hourly values of rainfall at the four Observatories : Aberdeen, Eskdalemuir, Richmond and Valentia ; also monthly totals of duration in each hour. For Richmond, Surrey, daily values of water level in a well are given.

The *Book of Normals* (M.O. 236, Section V) contains monthly and annual values of average rainfall for the period 1881–1915 at 578 stations, and also general averages for the British Isles and its major divisions. Monthly averages of the number of rain-days at certain stations will be

[11] In the nomenclature of the British Rainfall Organization ' general value ' means the average for an area. In the *Weekly Weather Report* the quantity represented by the weekly (or seasonal) general value for a District is the space-average of the percentage of normal rainfall in a given week (or season) at five selected stations in that District. This value is briefly referred to as the ' District value.'

found in the *Book of Normals*, Section I. Section II contains weekly, monthly, quarterly, half-yearly, seasonal and annual normals for Districts. Section III contains small-scale maps showing the monthly and annual average distribution of rainfall over the British Isles. Section IV includes tables showing the range of variation of rainfall and of the number of rain-days at twenty-eight stations.

Mention should also be made of the *Rainfall Atlas of the British Isles*, published by the Royal Meteorological Society. This contains monthly and annual maps of average rainfall, two maps showing the distribution of rainfall in the wettest year (1872) and the driest year (1887), and a series of maps showing the distribution of rainfall as a percentage of the normal in each year from 1868 to 1923. The Introduction, by Dr. H. R. Mill, gives the history of the British Rainfall Organization and contains a valuable discussion of the data represented in the charts.

Averages.

The standard period for which averages are calculated is 1881–1915. One of the aims of the Organization is to produce a map of Annual Rainfall for the whole of the British Isles, on the scale 2 miles = 1 in. The importance of completing this map was stressed by the Water Power Resources Committee in paragraph 276 of its Final Report. The position (December 1931) is now as follows :—

England and Wales 1881–1915 (Rainfall Survey) maps completed for about two-thirds of the area ; work now in progress on Cumberland, Leicestershire, Rutland, Gloucestershire, Bucks, Berks, Herts, Middlesex, London and Cornwall. Remainder of area already mapped by Dr. H. R. Mill, but not for standard period.

Scotland 1881–1915 maps completed for about half the area. Of the remainder about half has already been mapped, but not for standard period.

In drawing these maps all available information is used, averages for stations with short records being weighted to the standard period by comparison with nearby stations having standard averages. The averages so computed are included in Part III of *British Rainfall*. Reduced copies of specimen maps and a description of the method used in their preparation are given in articles published in Part IV of *British Rainfall*, 1928 and 1929.

It should be emphasised that the Rainfall Survey maps are not regarded as representing the ' last word ' on the subject of the rainfall of a specific small area. If required to produce a map, e.g. for the purpose of a water supply scheme, the British Rainfall Organization would prefer to go over the ground again, and in its final form the map might differ slightly from the original Survey map, where the lines are naturally somewhat generalised. *Ad hoc* maps for such purposes can usually be prepared at short notice even for areas not yet covered by the Survey.

Run-off.

The British Rainfall Organization is not, in present circumstances, officially concerned with run-off. The volumes of *British Rainfall* contain, however, certain data which are related to this aspect of hydrology. Each volume contains a chapter on evaporation and percolation records. *British Rainfall*, 1931, contains values of rainfall, percolation and calculated evaporation at four stations, and of evaporation measured from a free water surface in a tank at twelve stations.

Professional Work.

The Organisation is frequently consulted in connection with the evaluation of rainfall for water supply or water power purposes, and any such evaluations included in Water Bills generally rest on the authority of the Organization. Work of this character is regarded as 'professional work' and is performed under the terms set out in an official form (Form 928) which requires the applicant to sign a form of agreement (Form 927). In the form of agreement it is definitely stated that 'the opinion and advice shall be limited to consideration of rainfall, and shall not extend to such matters as evaporation, percolation, run-off, or other cognate questions.' In brief, the Organization is prepared to accept responsibility for estimating the average amount of rain that may be expected to fall on an acre, but is not prepared to estimate how much of it may be available for purposes of consumption or power.

Other Inquiries.

The records of the Organization may be consulted free of charge at the Meteorological Office, Exhibition Road, S.W. 7, between the hours of 10 A.M. and 4 P.M. on Mondays to Fridays, 10 A.M. to 1 P.M. on Saturdays. Replies to inquiries which can be dealt with by reference to the files of rainfall data are furnished at a small charge to cover the cost of the clerical work involved.

Research Work.

Original papers on rainfall and associated subjects are included in Part IV of *British Rainfall.* Recent volumes have included important papers on the exposure of rain-gauges by F. Hudleston, M.Inst.C.E. Lists of published papers will be found in the volumes for 1925 and 1900. A short bibliography of the more important papers on the rainfall of the British Isles which have appeared in *British Rainfall* and elsewhere is appended.

Short Bibliography of Papers relating to the Rainfall of the British Isles.

M. de Carle S. Salter : *The Rainfall of the British Isles.* University of London Press, Ltd.

C. E. P. Brooks and J. Glasspoole : *British Floods and Droughts.* Ernest Benn, Ltd.

H. R. Mill : 'Mean and Extreme Annual Rainfall over the British Isles,' *Proc. Inst. Civil Engineers*, 1903.

H. R. Mill and M. de Carle S. Salter : 'Isomeric Rainfall Maps of the British Isles,' *Q.J.R. Meteor. Soc.*, vol. xli, 1915, pp. 1–39.

J. Glasspoole : 'The Fluctuations of Annual Rainfall,' *British Rainfall*, 1921, pp. 288–300.

M. de Carle S. Salter and J. Glasspoole : 'Fluctuations of Annual Rainfall considered Cartographically,' *Q.J.R. Meteor. Soc.*, vol. xlix, 1923, pp. 207–225.

J. Glasspoole : 'A comparison of the Fluctuations of Annual Rainfall over the British Isles,' *British Rainfall*, 1922, pp. 260–266.

J. Glasspoole : 'Fluctuations of Annual Rainfall : A comparison of 35-year Rainfall Averages over the British Isles for different groups of 35 years falling in the period 1868 to 1921,' *British Rainfall*, 1923, pp. 238–256.

J. Glasspoole : 'Fluctuations of Annual Rainfall, Three Driest Consecutive Years,' *Trans. Inst. Water Engineers*, vol. xxix, 1924, pp. 83–110.

J. Glasspoole: 'Fluctuations of Monthly Rainfall,' *British Rainfall*, 1922, pp. 234–259.
J. Glasspoole: 'General Monthly Rainfall over the British Isles, 1881 to 1924,' *British Rainfall*, 1924, pp. 256–266.
W. N. McClean: 'An Analysis of Scottish Rainfall Records. Rainfall of the driest periods of one month and upwards,' *Trans. Inst. Water Engineers*, vol. xxx, 1925, pp. 95–118.
J. Glasspoole: 'Average and Extreme Seasonal Rainfall over the British Isles,' *Trans. Inst. Water Engineers*, vol. xxxiii, 1928, pp. 51–69.
J. Glasspoole: 'The Distribution over the British Isles in Time and Space of the Annual Number of Days with Rain,' *British Rainfall*, 1926, pp. 260–279.
F. Hudleston: 'Experiments with Rain-gauge Shields at Hutton John, Penrith.' Reports are included in *British Rainfall*, 1926, 1927, 1928, 1929, 1930 and 1931.
J. Glasspoole: 'Areas Covered by Intense and Widespread Falls of Rain,' *Proc. Inst. Civil Engineers*, 1930.
J. Glasspoole: 'The Reliability of Rainfall over the British Isles,' *Trans. Inst. Water Engineers*, vol. xxxv, 1930.
J. Glasspoole: 'Heavy Falls of Rain in Short Periods (two hours or less),' *Q.J.R. Meteor. Soc.*, vol. lvii, 1931, pp. 57–64.
A. A. Barnes: 'Rainfall Reviewed, A Common Long-average Period for each Country of the British Isles,' *Q.J.R. Meteor. Soc.*, vol. lviii, 1932, pp. 126–142.

Sub-Memorandum *C* (1).

RAINFALL DATA IN RELATION TO INLAND WATER SURVEY.

By E. G. Bilham.

In Memorandum C the arrangements for dealing with rainfall data, as they exist at present, are briefly described. It is now proposed to consider the particular aspects of rainfall which call for attention in relation to inland water survey. The subject may be treated conveniently under two main headings :—(I) The type of data needed, and (II) The arrangements necessary for supplying the data.

I. The Type of Data needed.

In any study relating to inland water, whether surface water or underground water, the rainfall is of primary importance because it represents the starting-point in the sequence of physical operations, the final result of which is seen in the variation of river flow, of lake level or underground water level. One may assume that when an Inland Water Organisation comes into existence it will have two main aims : (*a*) the determination, by direct measurement, of the amount of water that finds its way into streams or goes into underground storage ; (*b*) the investigation of the relationship between such amounts of water and the amounts which are deposited on the catchment area in the form of rain. The first essential, so far as (*b*) is concerned, is that there should be sufficient rain gauges in the catchment area and that they should be so exposed and distributed that reliable estimates of the general rainfall over the area during a given period can be made. Since the rise and fall of river level at a given gauge point

represents the integrated effect of the drainage over the whole catchment area above the gauge point, we must assume that changes of level in the river will be related to the general rainfall over the area, and the scheme of operations must be planned in such a way that the general rainfall can readily be evaluated as a matter of routine.

It may be remarked, in passing, that at any given season the fraction of the rainfall, incident on a given area, that finds its way into a stream depends on the geological characteristics of the area. This is of course quite well known, and the object of mentioning it here is to point out that in areas where there are wide variations of geological structure it may be necessary to make separate evaluations of the rainfall for subdivisions of the area based on geological considerations. This would be a point to bear in mind when selecting sites for rain gauges.

The next point that arises is the question as to how often it is necessary to read the gauges. For certain purposes, particularly the investigation of flood levels, it would be necessary to have continuous records of rainfall furnished by recording gauges, at least at a few points within the catchment area, but we must assume that the majority of gauges will continue to be ordinary gauges of the type in which rain is collected in a receiver and read by eye in a graduated measure. Hitherto it has been customary, in systematic studies of rainfall and run-off, to deal with calendar monthly values. That is, for example, the method adopted by the Thames Conservancy, whose reports show in parallel columns the total discharge in the month over Teddington Weir, and the general rainfall in that month in the Thames Basin above Teddington Weir. If that scheme were standardised as the normal procedure under the Inland Water Survey Organisation, it would suffice, therefore, if monthly totals of rainfall were available for all stations. In practice daily readings of rainfall are made by the majority of observers contributing returns to the British Rainfall Organization, the monthly totals being arrived at by summation of the daily readings. At certain stations, particularly in remote spots on mountains or moors, it is impracticable to read the gauge every day and the rainfall is, at such stations, normally allowed to accumulate for the whole month and then read.[12] There is no evidence to show that a monthly total measured directly in this way is not on the whole as reliable as a monthly total obtained from separate daily measurements. If the month is adhered to as the major unit of time for Inland Water Survey purposes, no need arises therefore for any change from existing practice in regard to rainfall measurements.

Captain McClean, however, has on more than one occasion expressed the view that a fixed interval such as a month is inappropriate, and that for such studies as are contemplated the days should be grouped into 'rain periods' and 'dry periods.' In this Memorandum we need only consider the pros and cons of that view in so far as they bear on rainfall data. From the observing point of view the only stations affected are those where gauges have hitherto been read only once a month. Captain McClean's proposal involves either reading such gauges daily or making use of some form of recorder, the chart of which when removed at the end of the month would yield readings for each day. The latter solution presents considerable difficulty, which will be realised when it is remembered that the instrument would have to work for a month without attention and would have to be fitted with some form of heating device to prevent its being thrown out

[12] At certain stations the gauge is read weekly, fortnightly or at irregular intervals, depending on the weather, as well as on the first of each month.

of action by frost. Experience shows, however, that if daily readings are available from a number of gauges in a given area, the monthly total measured in a mountain gauge can be apportioned with fair accuracy among the wet periods occurring in a given month. The loss of precision due to the absence of daily readings from particular localities would therefore not be very serious.

Given a sufficient number of stations with daily readings, supplemented by monthly totals at stations inaccessible for daily readings, the evaluation of general rainfall for rain periods presents no serious difficulty. The most accurate method of making such evaluations is to draw large-scale rainfall maps, measure the areas with falls between given limits, and thus arrive at the space-average or general fall. A quicker and only slightly less accurate method is to make a selection of stations, well spaced within the area, and determine by a preliminary investigation the relation between the arithmetical average of the falls of these stations and the general rainfall determined from maps. When this has been done the selected stations can be used for the routine evaluations and the maps can be dispensed with.[13] The number of stations need not be very great provided they are well distributed and the gauges are well exposed. It is found, for instance, that the arithmetical average of the falls measured at twenty-four selected stations in the Thames Basin gives a very close approximation to the monthly general rainfall deduced by a planimetric method from a rainfall map based on readings from over two hundred stations in the basin and its vicinity. Six stations suffice to yield an equally close approximation in the Lea Basin. When dealing with shorter periods than a month rather more gauges would be desirable in order to ensure that localised heavy rains were not missed, but it would appear unnecessary, in routine work on run-off problems, to deal with daily readings from more than a dozen or so gauges in each catchment area, the number depending of course on the size of the catchment. A close preliminary study of the rainfall in the area would, however, be necessary before the gauges whose records were suitable for such routine use could be selected. Such a survey would necessitate reference to the records from many more gauges than would suffice for routine evaluations of general rainfall, and it should be made clear that the British Rainfall Organization would always regard it as essential to collect records from all available gauges for the purpose of rainfall study in general.

Returning to the question of the time interval, my considered view is that while the study of rain periods may possess substantial advantages for dealing in detail with the run-off data for single catchments (such as might form the subjects of special memoirs), it would be necessary to adhere to definite calendar periods such as months, or groups of months, for the purpose of any regular periodical publication containing results from all the catchments participating in the scheme.

In regard to the use of recording gauges, I do not regard it as necessary to have many in each catchment area. For detailed study of particular falls, especially falls associated with floods, the records from one or more continuously recording gauges with daily charts would undoubtedly prove useful if not essential. Any such gauge should be in the charge of a competent employee, who could be relied upon to give it the necessary attention, and it would be necessary, in each case, to take daily readings for check purposes from an ordinary 5-in. gauge close to the recording gauge.

[13] The routine evaluations could, if necessary, be revised at a later date by the British Rainfall Organization, using the cartographic method.

Since the study of run-off involves questions of evaporation and percolation, it would be desirable to set up evaporation tanks and percolation gauges in each area. The word 'desirable' is employed because I think it would be well to encourage but impolitic to *press* water supply authorities and other participants to incur the expense of such installations, the value of which is problematical. I feel sure, however, that investigators would feel the need of some direct measurements—even rough measurements—of evaporation and percolation. In seeking the co-operation of authorities in any general scheme for Inland Water Survey, the desirability of installing evaporation tanks and percolation gauges, at least in a few of the more important areas, should therefore be borne in mind.

II. The Arrangements necessary for supplying the Data.

The British Rainfall Organization has always relied for its information mainly on data contributed voluntarily by interested persons. Among these, authorities directly connected with water supply have always formed a very important section. I assume that it will be the policy of any organisation formed for the purpose of Inland Water Survey to follow the lead of the British Rainfall Organization in this respect. If that is done I have no doubt that the Survey Organisation will have no difficulty in obtaining the rainfall data that it needs without expenditure other than perhaps a few small annual payments to observers in remote and thinly populated areas.

Except in so far as it will be necessary in some cases to improve the distribution of gauges over the catchment areas, it may be said that the means for supplying the rainfall data already exist in a fairly complete form. The need for more gauges in certain areas becomes very evident when it is recollected that in more than one recent water bill it has been necessary to make provision for the determination of the rainfall of the catchment area as a preliminary to the final assessment of compensation water. One of the first steps to be taken in any river basin where gauging operations are contemplated is to go over the ground for the purpose of ensuring that such rain gauges as already exist are giving satisfactory results, and to arrange for starting such additional records as may be necessary to secure satisfactory evaluations of general rainfall.

The gathering grounds under the control of existing water undertakings are, in the majority of cases, reasonably well furnished with rain gauges. Normally, therefore, it will be necessary to invoke the aid of private persons in extending the distribution of gauges into areas where the representation is unsatisfactory, and the fact has of course to be faced that the absence of human habitations makes it impossible in some areas to obtain readings through the usual channels. The Meteorological Office has itself installed gauges in certain remote areas, e.g., in the region above Borrowdale in Cumberland, and at Newbridge and Cranmere Pool on Dartmoor, and arranged for a monthly visit to be paid to the gauges by a local resident. In some cases a small annual payment is made for such services.

Whatever form the organisation for water survey may eventually assume, it is quite obvious that it will have to maintain a close liaison with the British Rainfall Organization. The liaison should extend to all matters relating purely to rainfall and should include :

(1) Advice by the British Rainfall Organization in regard to the selection of sites for new gauges and in regard to the reliability of records from existing gauges.

(2) Advice by the British Rainfall Organization in association with the Instruments Division of the Meteorological Office, in regard to instruments, including evaporation gauges and percolation gauges.
(3) The selection by the British Rainfall Organization of stations whose records should be used for routine evaluations of general rainfall.
(4) Co-operation with the British Rainfall Organization in obtaining additional observers where necessary.
(5) Avoidance of overlapping in regard to publication of rainfall data.

In regard to (5) it may be pertinent to point out that twenty years ago there were, in the British Isles, four separate bodies concerned in collecting and publishing meteorological data, viz. :—

The Meteorological Office.
The British Rainfall Organization.
The Royal Meteorological Society.
The Scottish Meteorological Society.

There is now only one such body, the Meteorological Office, of which the British Rainfall Organization forms a constituent part. This unification of control has taken years to achieve, and has proved advantageous to all concerned. Any arrangement made for the supply of rainfall data to the Water Survey Organisation should be such as to comply with the general principle of unification. It should not prove difficult to formulate a scheme under which the British Rainfall Organization maintained general supervision of the rainfall data, so that reports rendered by voluntary observers remained reports to the British Rainfall Organization, although the scheme might involve their passing through the hands of Water Survey officers at some stage.

Such are the general principles which should, I suggest, be kept in mind when framing an actual scheme for Inland Water Survey on a national scale.

Main Memorandum *D*.

SURFACE WATER.

By W. N. McClean.

1. Measurements and Records in other Countries.

In many other countries measurements and records of river flow appear to be better organised than similar work in the British Isles. Probably this is due to the particular problems to be solved and to the lack of rainfall records, such as those of the British Rainfall Organization.

The existing organisation of Inland Water Survey in other countries is dealt with in Memorandum B.

2. Measurement and Records in the British Isles.

All over the country a great many surface water measurements have been made, and in many cases there are long records of flow, or of water levels. Almost all of these measurements and records arise out of commercial developments of water and, as is only natural, the measurements made have been such as each development required. The measurements of a water supply authority are generally those of the actual supply, and of the water required by law to pass down the stream or river ; and there are usually no measurements of total run-off from an area.

Water power undertakings, canals, electricity power stations, pumping stations, etc., practically measure only the water that they use, or may require to use. Even with river boards, the total flow of the river has not been dealt with seriously. At most ports and harbours will be found automatic tide gauges recording the rise and fall of the tide ; but there are few of these to be found on any of our rivers, and generally a daily reading over a weir gives the estimate, by a laboratory formula, of the day's flow. If a questionnaire went round to all water authorities and river boards, the answers would probably indicate a host of measurements and quite a number of records, dependent on some semi-appropriate formula.

In these days, instruments and apparatus of considerable accuracy and efficiency exist for the measurement of river or stream flow. Measurements can be made in various ways, some of which, no doubt, require more experience for perfecting. The improved methods of measurement should be adopted, and with their adoption would come the keeping of continuous records of water level and flow at many important sites on our rivers ; and, in addition, records of rises and falls in lake levels, total flows from supply catchment areas, and water used daily in canals to cover evaporation, leakage and traffic.

From the measurements and records the engineer would be assured of the correct values of available water on which to base his scheme and to design the works.

Water authorities, corporations and individuals are in a position to keep the necessary records. Fishery boards, mill owners and water power companies, water supply authorities, canal and river authorities, boating associations, etc., have their data only in such a form as is sufficient for their own purposes. Every one of these individuals and authorities should be encouraged to see that, in the future, their measurements show not only what they themselves take but, when possible, how much they leave for others.

In the closely-woven pattern of water utilisation in our crowded country, no single interest can take away, divert, pollute, hold up, or change the flow of our rivers without affecting the interests and rights of other users. This country has, therefore, reached that stage when a comprehensive system of records of total flow is required in order that the quantities available may be known.

3. Water Survey in Relation to Land Survey.

The catchment areas of streams and rivers, the areas and depths of lakes, reservoirs, canals, etc., the lengths and sections of rivers, the sites of springs and the capacity of flooded areas are all ordinary survey work, and can be recorded on the Ordnance sheets or on suitable plans and tables. They are the static measurements of surface water, and once done only require keeping up to date.

All these measurements require accuracy, and if not actually made by our Ordnance Survey should at least be supervised by that authority. The Ordnance sheets to-day give the boundaries or river catchments, the sources of streams and rivers, and the sites of lakes, canals, etc., and some springs. On the Scottish maps the depths of all lakes are given, and of some of the English lakes the depths are known. Flooded areas are denoted to some extent on Ordnance sheets, and on main rivers the limit of tidal flow is shown. Subsidence areas require to be included where subject to flooding. The general slope of river beds requires some representation by longitudinal section, with the marking of critical points and the addition

of some standard sections of the river at likely points for water-level records and on typical reaches.

These static measurements are the foundation work on which to build the continuous records of water level and flow.

4. Rainfall, Storage, and Flow in Relation to Surface Water and its Measurement.

(A) *Rainfall.*—The measurement of rainfall by rain gauges distributed over a catchment area provides the primary assessment of potential flow in the stream or river. In the absence of flow measurements, the total flow during any period is estimated from such assessment of rainfall by deducting certain assumed losses. Those losses are, in fact, the estimated difference between rainfall and run-off derived from some specimen areas where rainfall and run-off have been measured over a long period of years.

In these specimen cases, the assessment of rainfall on the area depends on the method of working out the distribution, and must be uncertain unless there are a great number of gauges. In practice, the rainfall assessment is generally made for the year, and sometimes for each month. Even if the gauges are numerous and read daily, it would hardly be practical to make a daily assessment. On the other hand, the run-off measurement is a concentrated measurement which, with the proper apparatus, may be of great accuracy, and may be tabulated for any desired time interval—half-hour or three hours or the day. Owing to the present limitations of the rainfall assessment there is only an annual estimate of losses, and it is necessary to proportion this loss over the months of the year on the basis of the evaporation losses measured in a tank.

This method of estimating run-off from the rainfall has been developed on the foundation of our long rainfall records, and in certain directions it has been standardised and accepted as a legal measure of run-off. It is recognised that this indirect measurement of surface water run-off is unsatisfactory and productive of very erroneous results.

For accurate measurement of water, for any purpose, it is the actual continuous records of flow past a measuring point which are essential, and rainfall and other measurements then fall into their correct places for use in correlation to the measured flows.

The point emphasised here is that, in fact, the measurement of surface water has been dispensed with in practice, because there exists a cheap method of estimating flow from rainfall.

As one example of the danger of such an approximation one may take the example of the assessment of compensation flow (*Ministry of Health Advisory Committee on Water : Report of Technical Sub-Committee on the Assessment of Compensation Water.* H.M. Stationery Office, 1930). As other examples, one may take the cases of water power schemes, etc., where erroneous estimates of flow may make the scheme and wreck valuable existing interests or, conversely, may wreck a valuable scheme.

(B) *Storage.*—Dealing with the whole of a river catchment area, storage may take many forms, but, in its widest sense, storage is represented by certain natural and artificial physical characteristics of the area which modify the intensity, duration and volume of the flow. The need for continuous measurement of storage, in its relationship to flow, becomes at once apparent.

Principal forms of storage affecting surface water may be described as follows :—

(*a*) Snow and ice, increasing the flows of the late spring and causing, during a thaw, sudden heavy floods in the lowlands.

(*b*) Ground saturation, causing quicker run-off in floods and a slower fall after the cessation of rain.

(*c*) Tarns, lakes, reservoirs and canals, holding up and prolonging the floods and having varying effects on low flows.

(*d*) Flooded areas, ditches, etc., in the lowlands, reducing the peak intensity of flood flows.

(*e*) The capacity of the river channel and artificial channels in the lowlands, and of coastal embanked areas which keep out tidal flow. All of these affect the water levels and water slopes.

The measurements of evaporation and condensation, etc., are subsidiary to the main measurements and, in fact, cannot be ascertained except through analysis of the completed records.

The capacity for storage of different portions of a catchment is one of the principal factors governing intensity and duration of flood flows. When rainfall ceases, there are all descriptions of storage in action and, as the rainless period extends, the aggregate flow since rain ceased comes nearer and nearer to the measure of total area storage. An area will drain off in very similar fashion after each flood, subject to certain variants such as saturation or melting snow, etc.

Therefore, after rain ceases, the aggregate flow measures, firstly, the flood capacity of the river and some flooded areas : a most valuable measurement combined with land survey and river-bed survey and water levels. Later, the aggregate flow measures the de-saturation of the area. The rains which fall in summer and do not run off are also a measure of this de-saturation volume.

The continuous record of water level at carefully selected sites is the foundation of all problems connected with the various forms of storage.

When the areas of lakes and reservoirs are known at different water levels and the outflow is known, the rate of change in water level of such areas yields the inflow value.

When, on a river, the inflow to and outflow from a flooded area has been measured, the capacity of such flooded area can be estimated.

The times of concentration at various points on streams and rivers are a measure of area storage. This is particularly applicable to reservoired areas, when the interposition of a reservoir lengthens the period of concentration according to its volume and its weir dimensions.

In the control of floods, water level information on all these storage areas throughout the catchment and the knowledge of the times of filling and emptying such storages are of the first importance.

The bearing of storage on the maintenance of good low flows is obvious and probably requires no further comment here.

(C) *Flow.*—The River Basin is the obvious unit of area for the records of flow, and the general characteristics of the area will indicate the sites at which flow measurements should be made and at which continuously recorded water levels should be maintained. Gauge post water levels at numerous other sites will complete the picture.

The principal object should always be the measure of aggregate flow as obtained by continuity of water level records. The actual measurements of flow, for all water levels, at a selected site should be done once and for all with the utmost accuracy.

The aggregate flow which passes a gauging site during a flood or series of floods is only in a secondary manner affected by the configuration of

the river—sundry minor losses will vary according to the duration of the floods and the extent of flooding. Thus the aggregate flow of flood periods is a definite figure which may be compared with the rainfall; it is independent of the temporary effect of storage areas and of critical blocking points; it is a figure alike of natural and of controlled flow, to be amended only by definite figures of impounded storage and by figures of remaining or residual off-flow down to some standard low-water level.

The peak flows and their times at various points are due to configuration, natural or artificial, and their investigation gives the information required for river improvement or any required modification of storage and intensity of flow.

The characteristics of the river reaches which determine the selection of the actual flow gauging site are better left to the Memorandum on River Gauging; it is the characteristics of the whole river basin which indicate the general position at which flow measurements are required. It may be that artificial works will create a site for flow measurements. The values of flow at well-chosen sites will be the best basis for estimates of flow at intermediate points.

The selection of these sites and the continuous records of water levels should clearly come under the Catchment Boards; the actual measurements of flow at principal points should be carried out by trained men with the very best apparatus that can be devised.

A river basin may be subdivided in a general way as follows :—

(*a*) The uplands, mountain streams, tarns and springs and artificial reservoirs.

(*b*) Main tributaries and main rivers in narrow valleys with, generally, a considerable water slope and no extensive flooded areas.

(*c*) The same, passing through wide valleys with winding courses and sometimes lakes, and often with other considerable feeding streams.

(*d*) Lowland plains at the junction of tributaries or in the final estuary of the main river.

(*a*) Streams and springs are measured generally by weirs, preferably at the outlet of pools.

These measurements are made at present only in connection with water supply and water power schemes, and the records are often discontinued after the completion of the works. With regard to other springs and streams it is unlikely that much will be done at this stage, and knowledge of rainfall and of measured streams will suffice.

In any organisation of water measurements and records it is clear that water supply and water power authorities should instal apparatus for providing complete records of total run-off from their catchment areas.

Undoubtedly these water supply and water power areas afford an excellent theatre for complete water measurement. A great number of rain gauges may be installed with daily readings and possibly others of a recording type.

With suitable apparatus for the recording of water levels and flow, not only may the total flow be ascertained for any short or long period of time, but, in addition, accurate values of flow over different weir crests may be ascertained. Also, valuable data will be obtained, on the reservoirs, of the period of concentration of floods on upland areas.

All this data has already been called for by the Floods Committee of the Institution of Civil Engineers in order that a knowledge of flood flows may allow of correct design of reservoir spillways. Such data will eventually

place the settlement of compensation water on a proper footing and save considerable outlay on works.

(*b*) The narrow valleys where the river is confined during floods are distinctly suitable for flow measurements, especially if a pool reach is available or can be made by inserting a sunken weir. Such sites are well adapted to accurate current meter gaugings.

(*c*) The open valleys and lake areas are eminently suitable for water level records which, coupled with flow measurements at the outlet from such areas, will give valuable information as to storage effect.

(*b*) and (*c*) will provide the principal flow measurement sites before the river emerges on the final lowlands. The continuous water level records may, in many cases, be maintained by canal undertakings or electrical power stations or river water supply stations or other works.

(*d*) Lowland plains : The flow in these lowland plains may be difficult to correlate with water levels as the water slopes will vary considerably with rising and falling floods and general backing-up effects. It would seem more advisable to concentrate on measurement of channels, and so forth, and on the installation of well-situated water level stations.

Improvements in storage capacity and, consequently, in water slope in these lowland areas appear to be the key to improved drainage ; and the fen areas are an example of what has been effected in this way. With increased capacity in the lowlands and with control of tidal inflow, quicker run-off through higher reaches may be aimed at without causing floods in the lowlands.

The difficulties of control of tidal inflow on a navigable river are present in the problem of the Thames floods below Teddington.

5. The Routine of Surface Water Measurements (excluding Rainfall).

Section (3) deals with the land survey side of areas, lakes, reservoirs, waterways, river channels, etc. These may be termed static measurements and the records of such measurements will lie, firstly, on the 6-in. or other scale Ordnance maps and, secondly, on such detailed plans and tables, etc., as may be necessary.

The routine of water measurements covers the following procedure :—

(*a*) Observational work on water levels.

(*b*) Checking and filing of observational work.

(*c*) Compiling the records on standard lines.

(*d*) Analysis and publication.

The measurement of river flow at gauging sites does not come under this routine work (see Memorandum F). The table of flows resulting from this measurement is used for the conversion of water levels into flows, at stages (*b*) or (*c*) of the above routine.

It is, however, quite likely that at some gauging sites the continuous measurement of maximum velocity will be additional to the water level measurements. There is need of a suitable recorder for this purpose.

(*a*) *Observational work : Water levels.*—Gauge posts read once or twice daily or occasionally.

Automatic water level gauges. Charts changed weekly. Clock winding. Checking of graphs with gauge post readings.

Returns to filing office with any comments.

Arrangements have to be made, in some cases, for payment to observers, for local repairs and maintenance, and for some system of supervision.

Storage and flow controls.—At locks, weirs, etc., on canals and rivers and reservoirs the openings of sluices and gates, etc., and times thereof, have to be recorded, in addition to water levels.

(*b*) *Checking and filing at the filing office.*—When the observers' returns come in, there is considerable routine work necessary in suitable tabulation of readings and in the completion of graphs with the necessary gauge post checks, etc. There will also be conversion of water levels into flows and the compiling of records from all the returns.

(*c*) *Forms of records.*—The main record will be a table of water levels and flows; and, generally speaking, it will be necessary to tabulate the water level and flow for each three hours of the day and to average these flows for the day.

During principal floods, on the smaller areas, a second table will be required, dealing with half-hour periods, the values for each half-hour being averaged before filling in the 3-hourly values on the principal table.

Total flows will be arrived at between one low water and the next low water, and these will be amended by any changes in reservoir storage and by values of remaining flow down to a standard low water; these latter values will emerge from the records in the course of a few years.

In some cases a diagram of water levels may be a convenient form of continuous record.

(*d*) *Analysis and publication: Analysis of records* (Summary):

- (i) Dry weather fall of a river, residual flow after cessation of rain and temporary storage on area. Estimates of low flow for extended droughts.
- (ii) Concentration times, rates of rise and fall, peak intensities and duration of floods.
- (iii) Aggregate flows of long periods. Impounded storage and overflow of reservoirs.
- (iv) Relation of flow to rainfall during flood periods and analysis of losses.
- (v) Comparison of gaugings at various points on a river and on similar rivers.
- (vi) Frequencies of flow magnitudes.

Publication.—Generally, the publication of records is in the form of an abbreviation of the full records kept.

A usual publication is a graph for the year, giving the day-to-day flow above a horizontal time scale.

Another form of publication is that of the daily frequencies of flow magnitudes for each month or year.

A more complete form of publication, amenable to analysis, would give the aggregate flow from some selected date and the residual flow and amounts of impounded storage at low-water levels.

6. Application of Routine to the various Water Interests.

One requires to visualise this routine work in action with the present-day organisations.

In what follows I am trying to visualise, in my own way, those little modifications and additions to existing measurements and records which will change the individual work of the several water interests into something which will embrace the whole survey of surface water in its passage to the

sea. It does not pretend to cover all points. It is intended to show that the quiet improvement, step by step, of our recording systems comes first, with only the helpful guidance of an advisory organisation such as might be developed out of the beginnings of my 'River Flow Records' if it were strengthened by a small Council or by formation of an Association to deal only with surface water.

Fishery Boards.—Fishermen on all our lakes and rivers have their gauge posts and sometimes recorder instruments; and observers are available. It is only necessary to arrange for the data to come into a local office for checking and tabulating. One would like to see, eventually, the preparation of monthly diagrams of water levels. Fishery Boards could often organise this basic work of water levels on our rivers.

Boating Associations.—The statement sent to the Committee by the Motor Boat Association is another indication of what may be done on the observational side, and here it would seem that the records should go to the Catchment Board offices.

This statement is long, and is very briefly summarised in Appendix D (2) (*f*). It has been compiled with much care, and there is no doubt that these associations are able to carry through very good work, as is exemplified by the charts of small harbours produced by the Cruising Association.

The Motor Boat Association might be a very useful body to assist in connection with records.

Riverside towns and villages.—Here again there should be no difficulty with the observational side. Supervision may be very necessary, as such centres often view this type of thing from a popular aspect.

Private estates.—There are often good opportunities for observational work on private estates; and experience shows that the best observers are those with a routine job throughout the year.

Water Supply Catchment Areas.—These areas are suitable for complete measurements and records, but the design of works and the control of flow and the diversion of water from natural catchments complicate the problem, and records of total flow are not often maintained.

The changes in incidence of flow, due to impounding, etc., do not in any way falsify the records of aggregate flow; and analysis of the records will give natural flow figures when required. In order that records of value may be obtained from these areas, the lay-out of the works should be designed for complete measurement, and the keeping up of records afterwards should be no side issue.

Eventually, it is likely that systematic arrangements for measurement of total flow will amend, with advantage, present-day measurements of water authorities.

The observational work covers rainfall, storage and flow. The checking and filing would fall to the authority's office, where also the presentation of records in suitable form would be dealt with and certain investigation would be carried out. Even some additional filing and recording of neighbouring stream or river sites might become attached to these centres. They would form the proper centre for dealing with the upland records of river catchments. Supervision and direction of these records should be under some superintendent of a central water survey authority.

Water Power Authorities.—On the observational side, these are in similar case to water supply areas, and they should not be inferior in the routine work of records; but here again, when the works are finished, routine measurements should be properly maintained although they may not be a commercial necessity.

Canals and waterways and locked rivers.—Lock-keepers are naturally the observers, and the canal engineer's office is obviously the place for checking and filing of the observational records. Final tables of flow should be prepared in somewhat similar manner to those of the rivers. If the routine were once established, the somewhat complicated details would soon be collected into suitable form. Without more investigation into canal work I am not prepared to suggest any special form of record. It is, however, important to realise that the lock of a canal or river is an accurate measurement tank which will give valuable information of the actual flow through sluices as efficiently as the tank below the Assuan Dam.

The other record work which falls within the scope of canal measurements is the keeping of neighbouring water level records and sometimes flows on the rivers and streams used or affected by canal water supplies.

Electrical Power Stations and other abstractors of river water.—At present these stations appear to be only concerned with low flows, whereas they will be, in the future, dependent for their supply on natural or artificial storage somewhere on the river system. It is rather insufficient that they should only make a few low flow measurements of their own : they should be responsible for the water level records at all stages of flow, and their records should go to the Catchment Boards. The measurements of river flow should be supplied to them by the river authority, and their own flow measurements should be only those of the water abstracted from the river.

Other users of water would likewise be responsible for maintaining continuous water level records under the direction of the Catchment Boards. The Catchment Boards should supply them with necessary flow values, and they should supply the Catchment Boards with continuous water level records and with the figures of their own supply or diversion of water.

Catchment, Conservancy and River Boards.—There might be a Committee of a few of these catchment board engineers to outline briefly how their measurements and records may be developed on lines which will make their offices the central record office for the water survey and records of their respective river basins. If these boards do not make the whole river survey a matter of first importance, there is the real danger that their measurements and records, like those of other bodies, will be developed only for the solution of their own urgent problems of drainage and pollution.

SUB-MEMORANDUM *D* (1).

WATER SUPPLY AUTHORITIES.

NOTES ON THE PRESENT POSITION WITH REGARD TO PUBLIC WATER SUPPLIES IN ENGLAND AND WALES.

By F. O. STANFORD.

PREFACE.

The provision of a supply of pure and wholesome water for public purposes has by its very nature a prior claim on the water resources of the country, and the following notes are intended to indicate, though very roughly, the manner and extent to which this claim is exercised.

The Ministry of Health, as the predominant authority (under Parliament) in this respect, has compiled a large amount of data and statistics on the

subject, latterly with the voluntary co-operation of the British Waterworks Association; and through the Advisory Committee on Water has conducted investigations of special branches of the subject.

To this extent the original demand of the Select Committee in 1910, referred to below, for reliable information has been met.

As regards the essential subjects of topography, geology and rainfall, the Government has provided a special department for each, and the Ministry has the benefit of their assistance and advice when required.

All recent consideration of the subject, however, points to the fact that the available data are deficient in two important respects, which are becoming increasingly urgent: viz. reliable information as to the volume of water obtainable and available for public supplies in different areas—(*a*) from underground sources, and (*b*) from surface sources. As the former become used up or diminish, increasing reliance must be placed on the latter.

Demand for a Water Survey.

Demands for a comprehensive inland water survey have been made so frequently that it is hardly necessary to recapitulate them, but one authoritative statement on the subject may be quoted as a starting-point. A Joint Select Committee of both Houses of Parliament appointed to consider the Water Supplies Protection Bill, 1910, stated, *inter alia*, that 'in view of the lack of reliable information as to water supply, especially from underground sources, and the manner in which local supplies were utilised, there was urgent need for a comprehensive survey of the water supply of the country and for the adoption of measures to conserve and dispose of water to the best advantage.'

As the result of the Committee's report, no further action was taken on the Bill, but later in the same year a return as to water undertakings in England and Wales was ordered by Parliament.

Return as to Water Undertakings, 1914.

This return was compiled by the Local Government Board, as the result of over 3,000 schedules sent out during 1911–13, and the information was for the most part correct up to January 1914. Amongst the particulars which could not be checked, however, are 'the quantity of water derived from each source and the additional amounts obtainable.'

With this return the Local Government Board issued a Preliminary Memorandum, from which these notes are largely derived.

In this return the undertakings are arranged in five sections, and the numbers of undertakings were as follows:—

Section.	Description of Undertaking.	No. of Undertakings.
I.	Separate Local Authorities . . .	786
II.	Joint Boards and Joint Committees of Local Authorities	34 and M.W. Bd.
III.	Companies with Statutory Powers . .	200
IV.	Companies without Statutory Powers . .	84
V.	Private Proprietors	1,055

This return is now nearly twenty years old. For the provision of reliable and up-to-date statistics arrangements exist between the Ministry of Health and the British Waterworks Association, under which the Association now collect and publish statistical information. The third edition of the *British Water Works Year Book and Directory* contains a large amount of useful information respecting 871 undertakings, including Ireland.

Since 1914 very extensive developments of waterworks have taken place throughout the country, and are constantly taking place, but though some new undertakings have been established, these developments are chiefly in the nature of extensions of existing undertakings, and the above figures sufficiently indicate the magnitude of the subject.

The 1914 Memorandum states that 'out of 12,869 parishes in rural districts, 4,874 had a piped supply to some at least of their houses.' This number has since been very largely increased, especially by comprehensive schemes for groups of parishes; but much yet remains to be done to keep pace with the increased demand consequent upon improved standards of sanitation, such as W.C.'s, baths and hot and cold water supplies laid on to houses, which have greatly increased the consumption per head throughout the country.

The same memorandum states: 'the Return may be regarded as the first instalment of the detailed and comprehensive investigation of the whole subject of surface and underground water supplies which has been recommended by various Royal Commissions and Committees.'

Ministry of Health Water Survey and Advisory Committee.

The outbreak of the war shortly after the publication of the 1914 Return put a stop to further investigation for the time being.

Following the First Report of the Board of Trade Water Power Resources Committee, published in 1921, the Ministry of Health established a Water Survey for the compilation of data relating to water undertakings in greater detail than in the 1914 Return, including gaugings of springs where available. This, though of great use in the department, is of limited scope and confined to data obtainable from the respective undertakings, no special staff being available for making special investigations. The survey is not available in any published form.

The Minister also appointed an Advisory Committee on Water who have published a number of Reports, including:—

(*a*) On Measures for the Protection of Underground Water (1925).
(*b*) Report of Legislation Sub-committee (1929).
(*c*) On Rural Water Supplies (1929).
(*d*) On the Assessment of Compensation Water.

The Committee, in 1930, appointed a Sub-committee on the subject of river gauging; the work of this Sub-committee is, however, at present in abeyance owing to the urgent need for national economy.

The subject of underground water, on which the Select Committee of 1910 laid emphasis, is dealt with in a separate memorandum, by Dr. Bernard Smith, and it is only necessary here to mention the chief points referred to in the above Report (*a*), viz. the interference with underground water caused by mining operations and pumping; the waste of water arising from such pumping and from overflowing boreholes; and the need for the protection of underground water from contamination.

As regards legislation, the chief point affecting a water supply is probably that relating to the powers of a local authority operating under the Public

Health Acts to acquire water rights and abstract water. The powers are thus stated in the 1914 Memorandum previously referred to :—

'Common Law. In England and Wales under the common law every landowner has the right to use water flowing in known or defined channels, i.e., the water naturally flowing through, past or under his land, both for his domestic use and for his cattle, without regard to the effect of such use upon the landowners lower down the stream. Further, he has the right to use the water for any purpose, provided there is no interference with the rights of other landowners either above or below. He cannot however lawfully abstract from any stream water for sale or for the supply of the inhabitants of any neighbouring area. As regards underground water not flowing in defined channels, every landowner has the exclusive right to all water obtainable from his land.'

Consequently, local authorities who desire to use surface water as a source of public supply must in general, with few exceptions, obtain authority by special Act of Parliament. Any alteration of the general law which would simplify the procedure, e.g. by enabling the necessary powers to be given by Order instead of by Act (as recommended by the Select Committee in 1910 and proposed in a Bill introduced by the Government in 1911–12, which, however, did not proceed), would doubtless lead to some considerable increase in the use of such sources, and the necessity for gauging streams and the run-off from gathering grounds would become of the first importance in this connection.

As regards the assessment of compensation water, the Report (*d*) mentioned above recommends certain alterations in the present method, including—

'Stream gaugings should be used for the determination of the losses due to evaporation and absorption.

'Stream gaugings should also be used to measure and allow for the variability of flow.'

The Report (p. 11) mentions only ten different catchment areas for which continuous stream gaugings were available, and of these four cases were selected for detail analyses on which the conclusions were based. In a paper on this subject read before the British Water-Works Association in 1929, Mr. Fawcett (then Chief Engineering Inspector, Ministry of Health) pointed out that 'with some exceptions very little reliable data exists of the flow of rivers as ascertained by actual gaugings, and the Sub-Committee have felt acutely during their investigations the necessity for more records of river flows.'

Mr. Fawcett continues : 'As regards the various purposes for which river gaugings are desirable, it is only necessary to mention (1) water supply, (2) industry and power, (3) flooding, etc., (4) dilution, (5) navigation. There cannot be any doubt but that water supplies take the first place as regards importance of river gaugings.'

Reservoirs (Safety Provisions) Act, 1930.

The passing of this Act, which follows the recommendation of a Select Committee as far back as 1865, has brought into prominence the necessity for reliable and continuous record of the flow from upland gathering grounds, in order to furnish actual figures of the intensities of floods which require to be discharged by overflow weirs and channels, in preference to placing reliance on formulæ and estimations based upon rainfall for this purpose.

This subject is now under the consideration of a Committee of the Institution of Civil Engineers, whose preliminary report, it is understood,

recommends that suitable recording gauges should be set up for this purpose on rivers, lakes and reservoirs.

As a consequence of this Act and stimulated by the findings of this Committee, it may be anticipated that this branch of water engineering will receive increased attention in the future on those undertakings which possess large storage reservoirs for upland water.

Sources of Supply.

Referring again to the Local Government Board Memorandum, 1914, and classifying lakes, ponds, rivers and streams as surface supplies, and wells and springs as underground supplies, the principal sources at that date were :—

Lakes.—Thirlmere, Crummock, Hayeswater and Ennerdale.

Rivers and streams.—One hundred and thirty-nine undertakings use these as sources of supply, some of the most important of which are river Thames and its tributaries Lee and Kennet; river Severn and tributaries Avon, Chelt, Wye and Elan; river Derwent; river Tees and tributary Balder.

Upland surfaces.—In some cases it is not possible to differentiate between supplies derived from upland surfaces and from rivers, streams, lakes and springs, but approximately 167 undertakings depend upon gathering grounds for the whole or part of their supplies.

Special Acts authorising the abstraction of water from upland surfaces invariably contain provision for compensation either in money or generally in compensation water.

Springs.—The actual number of springs from which supplies are obtained is not known, but it appears that springs are among the sources of supply of 520 undertakings.

Underground sources, excluding springs, comprise wells, borings, adits and headings, etc. These furnish supplies to 495 undertakings.

For some years the supply from underground waters has been increasing, and the proportion of underground to surface waters used has been constantly growing. At that date the amount of underground water supplied was put down very roughly as 285 million gallons a day, and particulars are given showing roughly the amount derived from each geological formation.

In this connection it is pointed out that surface water is generally filtered, whereas underground water, including that from springs, as a rule is not.

Regional Water Committees.

In 1928 the Ministry issued a booklet (approved by the Advisory Committee on Water) recommending the formation of regional water committees in districts where a number of undertakers are concerned in the same general sources of supply, and where a common water policy is much to be desired.

Several such committees have been formed, e.g. the Sherwood Area Regional Advisory Committee (mentioned in the *Ministry of Health Annual Report*, 1931–32), comprising twenty-four local authorities whose supplies are derived from the Bunter sandstone beds.

In this booklet the Ministry points out, with regard to surface supplies, for which in few instances are accurate records available :—

'It is often necessary to become committed to a source of supply on such information as is available before accurate records can be obtained, but the earliest opportunity should be taken to instal proper gauges.

'The collection of reliable data by the Committee will represent a valuable part of their work.'

Conclusion.

From the foregoing notes it will be seen that the demand for records of underground water and river gaugings is general and persistent for purposes of water supply. The onus of providing these data must in the first place fall upon the water authorities for whose benefit they are primarily required, as, for instance, in the matter of compensation water, and whose works create the liabilities such as have given rise to the Reservoirs (Safety Provisions) Act. Further, it is on their property that the observations must be made, and their staff are on the spot to make the records. Water authorities, however, with few exceptions, have proved slow to realise that the slight expense involved would be for the advantage of their individual undertakings, as well as contributing to the wider knowledge essential for such bodies as regional water committees, and contributing also to the science of water engineering on which all such undertakings intimately depend.

It is highly desirable, therefore, that convincing efforts should be made to enlist the co-operation of the water authorities.

When this is secured, water engineers should have no difficulty in establishing some appropriate body of experts to give any advice that may be desired as to the methods of observing and recording, and to compile the results and draw conclusions of value to all concerned.

Appendix *D* (1) (*a*).

RECORDS OF WATER SUPPLY AUTHORITIES (GRAVITATION SUPPLIES).

By C. Clemesha Smith.

It is probable that many of the stream-flow records, etc., kept by water supply authorities are not in a form which would be serviceable to others than themselves.

The regulating effects of impounding reservoirs, the existence of catchwaters, tunnels, and conduits which convey the whole or a portion of the yield of one catchment area to another, the delivery of compensation water either intermittently or continuously, the drawing at irregular rates of supply, all render it necessary that adjustments should be made if the yield of a given catchment area is to be arrived at.

The records may be used in two distinct ways :—

(*a*) To show the actual yield of the catchment area in such a form that it may be compared with the rainfall for stated periods, and, by subtraction, show the losses by evaporation and absorption.

(*b*) The quantity which passes down the stream as compensation water and as unstored flood water.

Water undertakings reasonably organised should generally be able to furnish the following data in respect of their catchment area :—

Rainfall.—The average rainfall over the area for each year, for each month, and for specific dry or wet periods. (*Note.*—Automatic recording gauges are fixed on a few catchment areas. An extension of their use is desirable.)

Run-off.—

(*a*) (i) The total run-off from the area.
(ii) The monthly run-off from the area.
(iii) The total run-off for specific dry or wet periods.
(iv) Daily and weekly run-off could be obtained from the records when necessary.

As regards peak rates of flow, these can in most cases only be ascertained approximately, few reservoirs having instruments recording the rise and fall of water level throughout the entire depth.

(*b*) (i) The annual run-off (overflow water and compensation) passing into the stream below the lowest reservoir.
(ii) The monthly run-off (overflow water and compensation) passing into the stream below the lowest reservoir.
(iii) The run-off for specific dry or wet periods.
(iv) Daily and weekly figures of a similar nature could be furnished when necessary.

Most undertakings reasonably organised aim at statistics in respect of (*a*) (i), (ii) and (iii), and could furnish also (*b*) (i), (ii) and (iii).

It would not serve any immediately useful purpose to work out (*a*) (iv) and (*b*) (iv) for the whole year. In most cases the adjustments are laborious and would only be undertaken where the results would be valuable.

It is very desirable that peak rates of flow should be ascertained in the cases of the maximum floods in each year, and undertakings should provide the necessary recording instruments.

Sub-Memorandum *D* (2).

CATCHMENT BOARDS.

By J. C. A. Roseveare.

The forty-six Catchment Boards set up by the Ministry of Agriculture and Fisheries, under the Land Drainage Act, 1930, have jurisdiction over 39,000 square miles, which is 67 per cent. of the area of England and Wales. Many of these statutory areas consist of a number of separate river-basins amalgamated for convenience in administration.

It is unfortunate for the purpose of water survey that these authorities do not cover the whole of England and Wales, but the Minister has power to set up additional Catchment Boards if necessary. The boards are representative of all the interests in the catchment areas, two-thirds of the members being nominated by county councils and county borough councils, and one-third representing lowland areas in the catchment area.

It will be admitted that a catchment basin is the proper unit for water survey as regards rainfall and river flow, but this is not entirely so when considering underground water, which may, in special cases, travel from one catchment basin to another.

In order to design works in the most economical way, Catchment Boards should know the maximum and minimum flows in their rivers, and should keep continuous records of the rainfall and the flow resulting therefrom.

It is suggested that these Catchment Boards should undertake the water survey of their respective areas. From information received from a few Catchment Boards, it appears that some are already taking steps to this end.

Appendix *D* (2) (*a*).

Paper by J. C. A. Roseveare.

On 'Land Drainage in England and Wales,' presented to the Institution of Water Engineers, at their Winter Meeting, on December 2, 1932.

The paper, and the discussion which followed, appeared in the winter number of *Water and Water Engineering.*

The paper describes the formation and constitution of the forty-six Catchment Boards under the Land Drainage Act of 1930, and gives information as to the areas, length of 'main river,' rateable value and other details of the catchment areas.

The paper and the discussion both indicate the lack of information as to river flows, the crudeness of the estimates of flood flows, and the need for accurate gauging.

Appendix *D* (2) (*b*).

THAMES CONSERVANCY.

(Reply to Questionnaire.)

By G. J. Griffiths.

(1) The gaugings of the river Thames are made at Teddington Weir, which is at the seaward end of the Conservators' jurisdiction. The river below Teddington Weir is tidal. The measurements are made of the water passing over gauge crests and weir overfalls and through sluice openings.

The water levels are recorded by continuous clock recorders at points some little distance upstream and down-stream of the weir.

The formulæ from which the calculations are made were evolved some fifty years ago, and though they are not entirely in accordance with modern formulæ, they are retained in order that the results may be kept comparative with those of the past. The estimated flow has been checked from time to time by current meter observations at various magnitudes of discharge, and, on the whole, close agreement has been found between the calculated gaugings and the current meter observations.

(The formulæ employed are given in the original statement.)

Current meter observations are taken at times for the purpose of ascertaining the flow at certain other parts of the river or of tributaries, particularly in periods of drought.

See Appendix F (*b*).

(2) Part of Teddington Weir is normal to the direction of the stream, and part is at an angle thereto.

The tail-water side being tidal, there is a considerable variation in the 'fall' from head to tail at the weir during the day. This differs from about 3 in. to some 10 ft. in periods of low flow, and from about 1 ft. 3 in. to 2 ft. in times of high flood.

The range of water levels at which flows have been calculated extend over some 6 ft. or 7 ft. on the headwater side of Teddington Weir, or over a range of 16·5 ft. on the tail-water side, the flows ranging from 33 cub. ft. to 37,000 cub. ft. per second.

At some other weirs upstream of Teddington the range is from 10 ft. to

14 ft. on the tail-water scale, but none of these represent the full 'natural' range between minimum and maximum flow, owing to the influence of the weir next down-stream, in artificially holding up the level in times of low flow. This feature renders a scale of flows for varying water levels very insensitive for low readings, but use is made of such station gauges for obtaining approximate estimates of flow when required. Water is 'drawn off' or abstracted from the Thames in very large quantities by the Metropolitan Water Board and other water companies. The quantities so abstracted are measured and calculated for each day and are added to the volume gauged at Teddington, the sum being then described as the 'natural flow' of the river.

With such numerous and varied methods of abstraction as are employed it will be obvious that the measurements and calculations of the quantities are somewhat complicated, and they are made in very considerable detail to ensure accuracy.

(3) Each lock (there are forty-six lock sites) is provided with a scale gauge at the head- and tail-water sides, and these are read and recorded at every gauge four times in the twenty-four hours. This is in addition to the automatic recorders at Teddington, and at certain other weirs.

There are at present no station gauges or automatic recorders on any of the tributaries, but at certain critical times (periods of very low flow) gaugings have been made of the tributaries.

(4) It may be mentioned that daily records of rainfall are taken at some seventeen stations distributed over the Thames Valley, and that daily rainfall averages, together with the records of natural and gauged flow, are printed monthly, and are available to the public at a charge of 1*s.* per monthly sheet.

Surveys of main tributary streams are in progress, and information respecting the rainfall, maximum and minimum flows of these will be obtained in due course.

It is in view for the future to establish a gauging station on each tributary from which daily estimates of the flow may be obtained, but for similar reasons to those mentioned in regard to the main river, there are features which render this a proceeding of considerable difficulty, and it is doubtful if the value of the results would at present justify the cost of obtaining them.

Appendix *D* (2) (*c*).

RIVER TRENT CATCHMENT BOARD.

(Reply to Questionnaire.)

By W. H. Haile.

1. *Methods of river gauging at principal site or sites.*—The weirs across the 'main river' generally are of an antiquated character and are unreliable for computing river discharges.

The more modern weirs are usually for the purpose of maintaining head-water for turbines. Part of the river flows over the weir, the remainder passing through the mill; thus the weir discharge is not the correct river discharge.

Up to date it has only been possible to take current meter observations for special Parliamentary litigation purposes. A start, however, has been made to take regular current meter readings in the river Trent, at all river levels, to obtain a rating curve of discharge. The site of the observations

is just above Beeston Weir, near Nottingham, above which all the main tributaries join the river.

Head- and tail-water levels of the eight main weirs across the Trent are taken three times daily by the Trent Navigation Company. The information is at our disposal at any time.

2. *Method of computing flows.*—At the site the Trent is 280 ft. wide. An accurate cross-section has been taken, subdivided into 20-ft. vertical strips, fourteen subdivisions in all. At the centre of each subdivision, velocity readings are taken vertically, approximately at 18-in. intervals. The mean velocity is computed from the plotted velocity curve for each subdivision, the total discharge being the sum of (area × mean velocity) for the fourteen subdivisions.

This series of observations is to be taken at all water levels to obtain a rating curve to cover all stages from low summer level to flood level.

Knowing the head over the weir crest for each calculated discharge, constants for the weir discharge can be obtained.

The instrument used is Troughton & Simms' 'Improved Current Meter.'

3. *Keeping of water level records* (near gauging site).—It is intended eventually to establish rating curves for the principal tributaries near their junctions with the Trent. On computing the rating curves, automatic recording instruments to give discharge of river at any water level will be installed at the various gauging sites.

APPENDIX *D* (2) (*d*).

GREAT OUSE CATCHMENT BOARD.

(REPLY TO QUESTIONNAIRE.)

By O. BORER.

1. *River flow gaugings.*—I have found no record of past discharge observations. The only discharge observations made by me were at Bottisham Lock, and for the lock gate sluices I used the formula

$$Q = \cdot 62 \triangle \sqrt{2gh} \qquad \text{(Love's Hydraulics).}$$

and for the drowned weir—

$$Q = L\left[3\cdot 1\left\{(h + h_a)^{\frac{3}{2}} - h_a^{\frac{3}{2}}\right\} + 6\cdot 4d\,(h + h_a)^{\frac{1}{2}}\right]$$

(Love's Hydraulics).

I have not yet taken any river discharge observations, but we shall do so in the Marsh Cut, where we are having a gauging site arranged.

The site selected has a straight uniform reach of $1\frac{1}{2}$ miles in length, and we are fixing gauges at each end and in the centre. We shall read the surface slope from the gauges and take direct discharge observations at the centre by—

(*a*) Surface floats, using the formula

$$V = \frac{C}{C + 25} \cdot V_s, \qquad \text{where } V = \text{the mean velocity,}$$

V_s = the maximum surface velocity,

and C is Bazin's coefficient for the H.M.D.

(*b*) By means of velocity rods, floating vertically in the stream and so giving the mean velocity in the vertical plane.

From the discharges so observed and the recorded surface slopes the correct value of N in Kutter's formula will be ascertained for this particular reach of river, and subsequent discharges will be calculated from the surface slopes as observed on these gauges.

The cross-section of the river at the centre gauge (which at this site is fairly stable) will be periodically checked to correct error due to any change in this.

2. *Current meter measurements* by velocity meter are being taken when observing discharges in rivers and drains.

3. *Water level records near flow gauging sites.*—No record by continuous recorders, but a record of gauges at important points read daily or twice daily has been kept for many years.

4. *Water level records at other sites.*—There are no recording gauges yet fixed, but eight recording gauges have been prepared and will be fixed within the next few months.

Appendix *D* (2) (*e*).

WEST RIDING OF YORKSHIRE RIVERS BOARD.

(Reply to Questionnaire.)

By J. H. Garner.

When my Chairman and myself met you in London last November I think we explained the steps which the West Riding Rivers Board have so far taken in regard to river flow gauging. You will find some particulars of our work in the special report on River Don Gauging and in the copies of the Annual Reports.

Up to the present three Lea Recorders have been fixed as follows: No. 1, river Don at Hadfields' Weir, Sheffield (this gauge is now owned by the Sheffield Corporation and supervised by the manager of the Sheffield sewage works); No. 2, river Calder at Kirkthorpe Weir, Wakefield; No. 3, river Aire at Beal Weir, near Knottingley. These recorders give a continuous record of rate of flow and level of water.

Gaugings have also been made on the river Rother at Canklow, and river Dearne at Hoyle Mill, Barnsley. In these cases the gaugings were made over a reach of each river by taking the widths and areas of sections at different water levels and ascertaining velocities by floats.

It will interest you to know that I am in negotiation with the engineer of the river Ouse (Yorks) Catchment Board with the object of establishing co-operation in regard to river flow gauging between the Catchment Board and the Rivers Board.

My Committee has authorised the expenditure of £100 for the purchase of another Lea Recorder. This will be fixed to work with a suitable weir on another river in the West Riding where no gaugings have hitherto been continuously made.

In the West Riding most of the rivers have been industrialised and there are many weirs, a good many of which the Catchment Board will no doubt be able to put into satisfactory condition for use with automatic flow recorders of the Lea type.

So far as the Rivers Board are concerned, the use of suitable weirs would appear to be the only direction in which gaugings can be made, as the Board have no staff which could be spared to devote the necessary time to making gaugings by any other means.

Appendix D (2) (f).

THE MOTOR BOAT ASSOCIATION

(83 Pall Mall, London, S.W. 1).

Abstract from a Memorandum on Inland Water Survey.

1. Introduction.

The Motor Boat Association appreciates the request of the British Association Committee to put forward views in connection with the organisation of water level survey records on rivers and lakes.

The M.B.A. is representative of owners of motor boats used solely for pleasure purposes. Its membership embraces owners in every part of the British Isles as well as owners on the Continent.

The Association understands that the terms of reference to the Committee are 'To inquire into the position of Inland Water Survey in the British Isles, and the possible organisation and control of such a survey by central authority.'

Whilst the Association not unnaturally visualises the benefit of such a survey from the point of view of navigation of such waterways, it is also not unaware of the extension of the benefits to such interests as power houses, fisheries, drainage, etc.

It is aware of the immense bearing which a comprehensive survey and official and regular collation of results must also have on the important subjects of industry and research. The latent power inherent in many of the inland waterways of the country can only be effectively harnessed and adapted to the best possible service of industry if those responsible for commercial undertakings can have recourse to some central body from whom they can secure up-to-date and comprehensive information as to the potentialities of waterways in areas in which they may be considering erecting factories, power houses, etc.

On the aspect of research little need be said. The importance of continued study into the inland waterways, conducted over a regular and duly notated period of time, will be apparent. There is opened up, by a comprehensive survey, a vast field for useful research into the changing conditions and influences of the inland waterways of the country.

Therefore, in putting forward suggestions as to the organisation for dealing with such a survey, the Association does so bearing all such interests in mind.

2. Need for Comprehensive Survey
3. Waterways to be Surveyed
4. Recording Stations . . . . . . (*not abstracted*).
5. Recording Instrument
6. Recording Authority

7. The M.B.A. as the Recording Authority.

. . . the further point emerges that the Association has at the moment the nucleus of the organisation required for the regular and systematic collection and tabulation of water level data. In its service arrangements it has, at many centres, its own official boatmen and honorary local representatives.

8. The Structure of the Central Authority (*not abstracted*).

9. Conditions as to Appointments.

There are, of course, various other directions from which the data can be collected, and the machinery in this connection may be summarised as

(i) Officials of catchment boards and waterway authorities.
(ii) M.B.A. and other boatmen.
(iii) Angling clubs.
(iv) Rowing and motor boat clubs.
(v) Specially engaged surveyors.

10. Finance *(not abstracted)*.

11. Availability of Data.

The Area Superintendents would be expected to have available, and in their custody, the data from time to time forthcoming as the result of the surveys, while tabulated information from the whole of the country would be maintained at and available from the headquarters of the central authority in London.

12. Conclusion.

It is appreciated that the scheme as put forward by the M.B.A. is but in the nature of skeleton framework upon the broad conception of which much consideration of detail requires to be given if the proposal so suggested commends itself as worthy of further exploration.

The Grand Council of the M.B.A. would desire to assure the Committee of the British Association of its entire sympathy with the objects which its inquiry is designed to achieve, and in acceding to the request of the British Association to put forward its views the M.B.A. does so in the earnest desire to provide a constructive contribution to the question under consideration.

While it feels that it can, if thought fit, readily adapt within its present constitution the machinery necessary to enable it to undertake the important functions of a central authority such as is envisaged, it would equally emphasise the fact that, were it so desired, it would be ready to co-operate fully in the information and working of a separate central authority, to afford to such authority every assistance in its power, and to accord to it the hospitality of its office and organisation, and, in short, to do everything in its power to collaborate in the important work of inland water survey which it realises must, sooner or later, be adequately dealt with.

In conclusion, the M.B.A. would again express its appreciation for the opportunity of expressing its views, accorded to it by the courtesy of the British Association.

(Signed) C. Horton,
Secretary, Motor Boat Association.

Sub-Memorandum *D* (3).

WATER RECORDS KEPT BY HYDRO-ELECTRIC COMPANIES.

By W. T. Halcrow.

1. In the absence of records of river flow, all large hydro-electric schemes in Great Britain have been designed on an estimated yield of water from the catchment areas, based on rainfall records. Many millions of pounds have been spent on these undertakings, and it would have been of great assistance had long-period records of river flow been available for the engineers. Under present conditions there is an element of uncertainty in determining the economic capacity of such unalterable works as pressure tunnels,

as experience may show that the yield is either greater or less than has been anticipated; if the latter, unnecessary expenditure may have been incurred.

2. The hydro-electric works which have been constructed give an opportunity of recording the yield from catchment areas, and such information is helpful in dealing with adjacent catchments of similar character.

3. It is customary for the hydro-electric companies to prepare a balance-sheet of the rainfall and of water utilised and lost. The following information is usually recorded :—

(*a*) Year.
(*b*) Average rainfall on catchment area in inches.
(*c*) The level of the water in the main reservoirs on January 1.
(*d*) The increase or decrease of storage water during the year.
(*e*) Water lost over the spillway of dams as measured by continuously recording water level gauge.
(*f*) Losses from any subsidiary catchments not flowing directly to the main reservoirs, or water run to waste.
(*g*) Water utilised for power as measured over weirs or through Venturi meters.
(*h*) Total available water.
(*i*) Total water accounted for.
(*j*) Loss due to evaporation, absorption, etc., i.e. the difference between (*h*) and (*i*).

By means of these balance-sheets the yield from the catchment area is obtained, and, by measurement of exceptional increase in the rate of rise of water in the reservoirs, intensities of inflow owing to flood conditions and melting snow can be calculated; should the reservoir be full when such flood conditions occur the record of the flow over the dam spillway would also give a measure of the flood conditions.

4. I believe that the hydro-electric companies would be willing to give information of the yield of catchment areas to a central authority. It is possible that existing systems of recording data may require modification to bring them into accord with any recommendations of a central authority.

Sub-Memorandum *D* (4).

ELECTRICITY STATIONS.

By Henry Nimmo.

There were 454 stations owned by authorised electricity supply undertakers in operation at the end of 1932, against 483 in 1931 and 511 in 1930. With the coming into operation of the grid the decrease will be more rapid in the next two or three years, until only about 120 selected stations are left to generate all the electricity required by authorised electricity supply authorities.

In addition there were, at the end of 1932, 50 (against 55 in the previous year) stations owned by railway, tramway and certain non-statutory bodies, and there are still a large number in factories, mines, etc. The number of these, however, is expected to decrease rapidly when the full effect of the grid scheme takes place.

At the end of 1932 there was installed in the stations of authorised undertakers over 7 million kw. of plant, of which nearly 97 per cent. is steam driven, the remainder having oil and gas (about 2 per cent.) and over 1 per cent. water-driven prime movers.

The maximum load on the stations of authorised undertakers was of the order of 4 million kw., and 12,225 million kilowatt-hours were generated during the year, the load factor approaching 35 per cent.

In steam-driven stations the water in use in the steam cycle is used over and over again with an addition of from 2½ to 5 per cent. to make up for leakage and other losses.

The amount of circulating water required varies with the design and layout of the station. Under existing conditions of load factor, approximately 60 gallons are required per unit generated, and the total quantity used by authorised undertakers (including oil- and gas-driven stations, using about 4·5 gallons per kw. of plant in operation) is equivalent to something like 300 million gallons (one and one-third million tons) per hour for 3,060 hours, or a total of over 4,000 million tons in the year. For every ton of coal consumed in these stations about 500 tons of circulating water is needed.

In this connection steam-driven generating stations may be classed under three heads, viz. :—

(1) Those using tidal water, like Battersea and Barking (where 22 million gallons per hour may ultimately be handled), which are only limited by the size of the intake tunnels and pumps.

(2) Those using river or canal water ; and

(3) Those with a limited supply from wells or other sources and having cooling towers so that the circulating water may be used over and over again. In this case from 3 to 5 per cent. is lost in evaporation.

With a single station ultimately handling up to 22 million gallons per hour, the provision of an adequate supply of water is of first importance, and this accounts for the fact that all large new stations are either placed on a river bank or within reach of tidal water.

In the annual questionnaire sent out by the Electricity Commissioners to all electricity supply authorities, those with generating stations are requested to state, under the sub-heading 'Condensing Facilities,' (i) the source of water supply (stating whether tidal water, non-tidal river, canal, etc.) :—

(*a*) Minimum dry weather flow in gallons per hour.

(*b*) Normal usable flow at other times in gallons per hour.

This information, though not complete, is therefore available in respect of a large number of stations. The flow of many of the rivers has been measured from time to time, and a list is available giving details of flow in respect of fifty rivers in England and Wales and the method of gauging at thirty-seven.

Unfortunately, in many cases very rough-and-ready methods have been employed and some strongly conflicting results obtained. A few have been measured with some degree of accuracy, but none over any extensive period of years. While the results on the whole may not be of much value, they will serve to show what has been done.

One of the most careful and accurate measurements made was on the Severn at Ironbridge by the West Midlands Joint Electricity Authority, and details of this survey are given at the end of this memorandum. The Severn Navigation Board also gauged the Severn at Worcester and could no doubt supplement the information given here.

Some of the rivers have been gauged at several points—the Irwell, for example, at five different places—and some others at two or three ; among the latter the river Aire, which has been gauged at Bradford, Leeds and Ferrybridge. When the Bradford Corporation Station at Esholt, on the Aire, was under consideration, the City Electrical Engineer, Mr. Thomas Roles, had gauging records of the flow taken from 1917 to 1921 (see details attached). Upstream from the power-station site the river had been impounded many years ago for supplying water power to a factory, and the dam wall was adapted by Mr. Roles for the construction of a weir 115 ft. long and 12 in. deep, and a flute chamber some 10 ft. upstream

was built in the river bank, into which a seven-day Lea Recorder was installed to measure the rate of flow. These observations were discontinued in September 1921, but Mr. Roles thinks this gauging station could be re-established at a cost of £50 to £100.

In regard to underground water, some information is also available in respect of wells at various power stations, but no systematic flow measurements appear to have been made.

Appendix *D* (4) (*a*).

GAUGING OF THE RIVER SEVERN AT IRONBRIDGE

BY THE WEST MIDLANDS JOINT ELECTRICITY AUTHORITY.

By E. F. Hetherington.

Ironbridge power station has been designed for an ultimate capacity of 200,000 kw., consisting of four 50,000 kw. maximum continuous-rated machines. When the construction of the station was under consideration in 1925–26 rough measurements of the river flow were made. In 1927 a further set of measurements was made, and a third survey was completed in the summer of 1928 after a long dry spell, when the flow was at its minimum. The result of these measurements showed that even under the extreme conditions prevailing in 1928 there was sufficient water for the operation of three generating sets at full load, the fourth acting as a standby.

Since that date constant observations have been taken, and a complete record of the daily river levels from June 1929 to the present day has been kept and a curve plotted.

The Authority is quite satisfied that during eight or nine months of the year there is more than sufficient water for the operation of 300,000 or 400,000 kw. of plant, and this being the case they have never troubled to gauge the river accurately at the higher rates of flow.

The method of gauging adopted was to select a certain stretch of the river and make an accurate survey of its depth. The particular length chosen for this purpose had practically the same depth contour throughout, and this considerably simplified measurements. The floats were designed and made of a type indicated on a plan which is available, if required. These floats consist of a kind of boat-shaped raft with a sinker weight, which could be arranged to hang down into the water at any desired depth, by which means a more or less mean velocity could be obtained between the surface of the water and the flow nearest to the river-bed. Levels were very accurately taken by theodolite, and lines were placed across the stream at two points, (*a*) and (*b*). The floats were timed over the course, and a velocity table attached indicates the rates of travel down stream. From time to time intermediate timings were taken, which clearly showed that the floats traversed the whole length of the course at a constant velocity. The cross-section of the river (copy available if required) worked out at 448 sq. ft., while the mean velocity of flow, as indicated on the table attached, was found to be 0·849 ft. per second, and taking the number of gallons per cubic foot as 6·25, the quantity of water was

$$448 \times 0{\cdot}849 \times 6{\cdot}25 \times 3{,}600 = 8{,}580{,}000 \text{ gallons per hour.}$$

The Authority has not troubled to take very accurate measurements of the higher rates of flow, although a number of tests have been made from time to time, from which it would appear that the normal summer flow of the river at this point is in the region of 12 million gallons per hour.

(Table of measurements accompanies original statement.)

Appendix D (4) (*b*).

BRADFORD CORPORATION ELECTRICITY DEPARTMENT.

River Aire at Esholt.

Gaugings at Buck Mill Weir.

Number of Hours per Month at Different Rates of Flow.

By T. Roles.

The original tables show the frequency of the hourly flow magnitudes for each month of each year. These have been summarised for each of the years 1918, 1919, 1920 and 1921.

1921 is without values for a period in April, May and June, and for the whole of October, November and December.

Year.	Hours Recorded.	Millions of Gallons per Hour.										Minimum Millions.
		Over 9.	8–9	7–8	6–7	5–6	4–5	3–4	2–3	1–2	Below 1.	
1918	8,760	2,399	250	324	370	912	1,007	775	1,131	1,317	275	0·4
1919	8,760	2,259	432	339	300	516	782	508	1,054	2,024	546	0·2
1920*	8,616	1,906	505	1,210	621	853	997	716	888	780	140	0·5
1921	5,160	813	60	81	93	141	239	408	679	1,290	1,356	0·1

* Nov. = 168 hours not recorded.

APPENDIX *D* (4) (*c*).

TABLE

ACCOMPANYING SUB-MEMORANDUM *D* (4).

By H. NIMMO.

The original table gives for each place and authority on fifty rivers :—
(1) Normal summer flow.
(2) Area of gathering ground.
(3) Minimum flow and month of occurrence.
(4) Method of gauging and remarks.

The following abridged table gives the areas and the normal summer flow and minimum flow in cusecs per thousand acres.

River (and County).	Thousand Acres.	Normal Summer Flow.	Minimum Flow.	Method.
		Cusecs per 1,000 Acres.	Cusecs per 1,000 Acres.	
Aire (Yorks) . . .	—	—	—	Weir
,, ,, . . .	244	2·9	1·3	Floats
,, ,, . . .	298	1·3	0·1	Weir
Avon (Hants) . . .	416	1·5	0·4	Meter
,, (Wilts) . . .	403	2·7	0·2	Weir
Calder (Yorks) . .	181	1·8	0·6	Floats
,, ,, . . .	206	1·4(av.)	0·8	Weir
,, (Lancs) . .	57	1·5	0·5	Weir
,, (Yorks) . .	101	3·8	0·5	Weir
Colne ,, . .	57	1·9	0·7	Weir
Dee (Cheshire) . .	439	2·1	0·6	Weir
Derwent (Derby) . .	270	1·8	0·7	Weir
,, ,, . .	300	2·9	1·5	Meter
Don (Yorks) . . .	91	3·4	1·2	Weir
Eden (Cumbd.) . .	640	1·3	0·6	—
Exe (Devon) . . .	412	1·1	0·6	Weir
Irwell (Lancs) . .	199	0·6	0·4	Weir
Nene (Northants) . .	403	0·5	0·3	Floats
Severn (Worcester) . .	1,046	0·5	0·3	—
,, (Salop) . .	704	0·7	0·5	Floats
Taff (S. Wales) . .	125	2·2	1·6	Floats
Taf Fechan (Wales) . .	25	2·1	0·5	—
Tame (Cheshire) . .	22	3·9	2·0	Weir
Thames (Oxford) . .	672	0·8	0·1	Floats
Trent (Derby and Staffs) .	704	1·2	0·2	Weir
Tone (Somerset) . .	83	0·9	0·4	—
Welland (Lincoln) . .	137	0·2	0·1	Floats
Witham ,, . .	38	0·4	0·1	Sluice gates

Sub-Memorandum *D* (5).

CANALS.

By T. Shirley Hawkins.

1. In considering what water measurements it may be desirable to take in the case of canal authorities it would first be as well to set out what different forms the canals may take, i.e.

(i) The artificially cut canal;
(ii) the combination of artificially cut canal and the canalised river;
(iii) the canalised river;

and with these large differences in type it will be seen that the number and character of the measurements required would vary for each of the three types.

2. There are, however, four common purposes for which all three types of canals require a supply of water, viz. to replace losses caused by :—

(*a*) Traffic requirements.
(*b*) Evaporation from the water surface.
(*c*) Percolation and absorption through the earth banks and waste due to leakage.
(*d*) Leakage at the lock gates and sluices and under and around the locks themselves.

The measurements, so far as (*b*), (*c*) and (*d*) are concerned, have not to my knowledge ever been accurately measured or gauged. The amount required for (*a*) is easily calculated, and the only quantitative knowledge we have so far as regards (*b*), (*c*), and (*d*) is the amount of feed water that has to be let down to keep the several reaches filled and to meet the traffic requirements, so by deducting the known requirements from the total we can find the necessary amount of water that is required for (*b*), (*c*) and (*d*), but I know of no means of separating these three into distinct units.

The leakage coming under (*d*) is often considerable and can be traced to faulty construction, the state of repair and maintenance, the careless closing of the gates, and to obstructions that get across the bearings of the stops, mitres and meeting faces.

3. I next come to the question of supply of water to meet these several requirements and they differ in all the three cases. Generally, supplies may be obtained from any of the following sources :

(i) By the rainfall over a catchment area which can be collected and stored in artificially made reservoirs.
(ii) By the flow directly into the canal of rivers, streams, etc.
(iii) The storage water obtained under (i) being taken to the canal either by gravitation or pumping, according to the level of the supply water in its relation to the canal water level.
(iv) By pumping water from rivers near by the canal, but which are at a lower level than the canal.
(v) By returning the water 'used up' by traffic to the higher reaches by means of pumps erected on the lower reach.

4. So far as the 'artificially cut canal' is concerned, its supply may be derived from all the before-mentioned sources, and a lot of very useful data could be obtained by arranging for systematic measurements being taken :—

At the *reservoirs* to ascertain the rate of fall in the level of the water in the reservoir due to the feed water supply that is kept on, and also

to ascertain the rate of rise in the reservoir due to 'run-off' from the rainfall.

Of the *amount of feed* water that is 'kept on' to supply the requirements set out under (*a*), (*b*), (*c*) and (*d*).

Of the *amount of feed* water that is 'kept on' at the individual locks together with recorded levels of the reaches both on up- and down-stream sides of the lock.

Of the number of lockings that occur daily at each lock.

5. So far as the 'combination of artificially cut canal and canalised river' is concerned, in this case no doubt fairly extensive weirs will be constructed on the various reaches for carrying away flood water, so in this type it would be desirable for records to be kept :—

At each lock of the level of the water in the reaches (up- and down-stream).

Of the amount of feed water that is 'kept on.'

Of the daily number of lockings at each lock.

Of the height of the water passing over the several weirs during normal and flood periods.

6. This introduces another subject which will certainly arise, i.e., what is the formula to be adopted for the calculation of the amount of water passing over the weir under various heads, and it is suggested that a very useful amount of experimental work could be carried out by gauging the flow in the artificial cuts carrying away the weir water to ascertain how the coefficient of discharge varies according to the types of weir constructed.

7. So far as the 'canalised river' is concerned, the measurements required will be practically similar to those necessary for the immediately preceding type, except that in all probability the weirs will be longer and larger, and we may also have the problem of mills being constructed athwart the river and absorbing a large amount of water, and arrangements for measuring the amount of water they consume should also be made in addition to the measurements to meet canal requirements. In many cases millers are responsible for the river and/or canal water level being kept too high or run too low in the several reaches both as regards canal working and also as regards the standing surface water level of the surrounding land.

8. Of the various sources of supply mentioned in paragraph 3, only the first has a sufficient and efficient organisation in existence to supply the necessary data ; the others are only dealt with by canal authorities to the extent that the efficient working of their canal demands.

9. No doubt the various canal authorities have a lot of information available, but whether they would be prepared to consent to this information being supplied to a co-ordinating body set up for the purpose is one that would have to be very tactfully ascertained from them, and this would form a suitable subject for discussion with the main Committee of which we are a Sub-committee, to ascertain from them how far they consider the matter should be pursued.

Sub-Memorandum *D* (6).

WATER POLLUTION AND RIVER GAUGING.

By A. Parker.

General.

Accurate information regarding the flow of rivers and streams, river levels and underground sources of water is of value not only in connection with

water supplies, land drainage, fisheries, hydro-electric schemes, electricity supply stations and various manufacturing processes, but also in attempts to control and prevent water pollution. The extent to which sewage or other polluting effluent ought to be purified is dependent partly on the dilution afforded by the river into which the effluent is discharged; the greater the dilution the more rapidly the river recovers as a result of self-purification processes. A knowledge of the flow of the river or stream concerned is therefore necessary if plant for the treatment of sewage and industrial effluents is to be designed and operated on the most economical lines.

Attention has been directed on many occasions to the importance of river flow data in relation to water pollution problems. The Royal Commission on Sewage Disposal, whose comprehensive inquiry during the period 1898 to 1915 dealt with the methods of treatment and disposal not only of sewage but also of trade effluents, definitely stated that the standards to be applied to sewage effluents should be adjusted according to the character of the streams into which they are to be discharged. The same principle undoubtedly applies to trade effluents. During the inquiry a considerable number of rivers and streams of different types were kept under observation with a view to tracing the effects of discharging various sewage liquids of known composition and volume into streams of known quality, volume and velocity; and the scheme of standards which the Royal Commission finally recommended for sewage liquids was based on the results of these observations. The value of river flow data in dealing with problems of pollution has also been stressed in each of the published annual reports of the Water Pollution Research Board of the Department of Scientific and Industrial Research since the appointment of the Board in 1927. In addition, references to this same application of measurements of river flow have been made in published reports issued by the Ministry of Health, the Ministry of Agriculture and Fisheries and the West Riding of Yorkshire Rivers Board, and in other publications.

Unfortunately, comparatively little information on the flows of rivers and streams in this country is available, with the result that in most instances the effects of discharges of polluting effluents on individual rivers cannot properly be assessed. As an example of the dearth of information of this kind, even for important rivers, reference might be made to the river Tees. Early in 1929, the Water Pollution Research Board began a comprehensive scientific survey of this river, with the object of obtaining reliable data regarding the quantities of polluting effluents of various kinds which can be allowed to enter a river without unduly retarding the natural processes of self-purification of the polluted river water. In this instance there were at the outset no gauging stations on the main river or its tributaries, and no reliable records of river flow and levels. The chemical and biological work of the survey had to be supplemented, therefore, by hydrographical measurements not merely of tidal currents in the estuary, but also of freshwater flows in the upper river.

In recent years the various authorities, undertakings and individuals responsible for dealing with pollution problems have undoubtedly begun to appreciate the importance of river flow data. A few have already made observations of the flows and levels of the rivers in which they are interested, and there are definite signs that, with encouragement, many others will be willing to arrange for river flow and level measurements to be made.

It may be asked whether the labour and expense likely to be involved in securing data on river flow can be justified in relation to the value of such data in dealing with pollution problems. In the first place river flow

data are necessary in deciding whether the discharge of a particular effluent to any individual stream is likely to cause nuisance or to endanger public health. Many rivers which are to some extent polluted will, in the future, have to be utilised after treatment as sources of water supply for both domestic and industrial purposes. In such cases more accurate information on the effects on rivers of various discharges and more careful control of the discharges will be required. Secondly, as already mentioned, data on the flow of the river concerned are necessary if plant for the treatment of sewage and industrial effluents is to be designed and operated on the most economical lines. It is not possible to estimate the expenditure involved in the satisfactory treatment and disposal of industrial effluents, but it must be considerable in view of the very large number of industrial undertakings in this country producing effluents which have to be treated and discharged into rivers and streams. As regards sewerage and sewage disposal, loans sanctioned by the Ministry of Health for expenditure on such works during the three years 1929–30, 1930–31, and 1931–32, amounted to £5,800,000, £8,900,000, and £7,740,000 respectively.

Rivers Pollution Prevention Authorities.

The principal statutory enactments relating to river pollution are contained in the Rivers Pollution Prevention Acts, 1876 and 1893, which are directed towards the abatement of pollution in the public interest generally, and in the Salmon and Freshwater Fisheries Act, 1923, which has in view the same object in the interests of fisheries.

The duty of enforcing the Rivers Pollution Prevention Acts was originally entrusted to the sanitary authorities, i.e. town councils and urban and rural district councils. Under Section 14 of the Local Government Act, 1888, county councils were given concurrent powers throughout their administrative counties. The same section also gave power to the Local Government Board (now Ministry of Health) to set up, by Provisional Order, subject to confirmation by Parliament, joint committees or similar bodies for the purpose of administering the Rivers Pollution Prevention Acts. Under this section three such bodies have been set up: (1) the Ribble Joint Committee, (2) the Mersey and Irwell Joint Committee, and (3) the West Riding of Yorkshire Rivers Board. Fishery Boards also have power, under Section 55 of the Salmon and Freshwater Fisheries Act, 1923, to institute proceedings under the Rivers Pollution Prevention Acts.

According to the general law at present, therefore, the power of enforcing the Acts of 1876 and 1893 is vested in:

(1) All town councils, and urban and rural district councils.

(2) All county councils.

(3) In respect of the Ribble, the Mersey and Irwell, and the rivers in the West Riding of Yorkshire, joint committees or rivers boards set up to deal with those particular rivers.

(4) Fishery boards under Section 55 of the Salmon and Freshwater Fisheries Act, 1923.

In addition there is a Joint Committee, without statutory powers to take legal proceedings, set up under Section 57 of the Local Government Act, 1894, in respect of the upper waters of the Tame (a tributary of the Trent).

The Upper Thames and the Lee are the subject of special legislation which has set up Conservancy Boards possessing wide powers of controlling pollution. Both these rivers supply the Metropolitan Water Board with

water for public supply. The powers granted to the two Conservancy Boards are greater than are given in the Rivers Pollution Prevention Acts.

Reference should also be made to a clause in the Land Drainage Act, 1930, which provides that a provisional order constituting for a catchment area or combination of catchment areas a joint committee or other body having any of the powers of a sanitary authority under the Rivers Pollution Act, 1876, may be made under Section 14 of the Local Government Act, 1888, by the Minister of Health of his own motion and without any application by the Council of any of the counties concerned. No joint committee or similar body has so far been set up under this particular clause.

From the preceding paragraphs, it is clear that the administration of the Rivers Pollution Prevention Acts is vested in local sanitary authorities, joint committees, fishery boards and other bodies on which the local authorities are represented. In dealing with problems of pollution and of fisheries, these bodies are definitely interested in river flow data, river levels, compensation water and similar matters. It is suggested that these bodies should in general be in a position to arrange for systematic measurements of river flow and river level, the results of which might then be sent to some central office for collection, correlation and, possibly, publication. Some of the local organisations mentioned are obtaining data on river flow, but in most instances no systematic observations have yet been made.

Main Memorandum *E*.

UNDERGROUND WATER.

By Bernard Smith.

1. Suggestions as to Observations and Measurements necessary.

In any organisation dealing with inland water resources accurate observations should be taken on the occurrence, amount and quality of the water stored underground in suitable permeable strata, and upon that which issues in the form of springs and seepages.

In some districts percolating water is stored in rocks of open porous texture such as certain sandstones, which form natural reservoirs lying between, or faulted against, impermeable strata in such a way that a definite measurable water-table is established; while in others it is stored mainly in systems of connected fissures and bedding planes (such as those in chalk), also with a fairly definite measurable water-table. In other cases, again, it occurs in more sporadic fashion, either (*a*) in thin, and at times discontinuous, permeable strata—as when thin beds of limestone or sandstone alternate with shales, or sandy lenticles occur in glacial clays—or (*b*) in irregular fissures from which isolated springs may arise, but in which no definite water-table can be determined—as in slates, granites, etc.

Beneath cover, and down dip, many of these rocks in their subterranean extension will yield water under artesian head when tapped by bores or wells.

In all cases the thickness, geological character and structures of the water-bearing rocks require careful study.

Water-tables.—It is essential that any measurable water-tables occurring in strata that fall within a definite drainage-basin should be studied in detail, and contours or cross-sections drawn to show their levels at three, four or more different periods of the year. For this purpose it is desirable to have standing water levels measured in a carefully selected series of wells, that tap water in the bed or beds undergoing observation, within as

small a time limit as possible (say one week or less) for each chosen period of the year. In some wells at which continuous pumping is not going on the levels might be taken daily or weekly and related to rainfall, percolation and evaporation. These would give a more continuous picture of the fluctuations of the water-table during the year.

Local co-operation would be necessary to gather widespread and consistent data for drawing contours; but the selection of the wells and the general supervision might be the task of a hydrogeologist. Some central authority is needed to encourage a standardised procedure and receive the necessary data for the construction of a continuous series of contoured maps.

The seasonal fluctuation in the water-tables at or near outcrop would appear to depend upon :—

(1) Percolation and evaporation; (2) issue from springs; (3) pumping.

At trial borings and established pumping stations records are needed of (1) the actual amount of water pumped (stating whether working at full capacity); (2) the maximum fall in water level during pumping; (3) the rate of lowering of the water level; (4) the rate of recovery after cessation of pumping; and so on. Cones of depression in the surface of the water-table should be mapped out and related to the diameter of the well or boring, the suction level, capacity of pumps, physical character of the water-bearing rock and other relevant factors.

Arising out of the plotting of water-table contours, the effects of pumping on the general, as distinct from strictly local, water-table over a number of years could be studied, and the results of overpumping—with possible deterioration of the water both in quantity and quality—properly evaluated.

Amongst associated rocks with different degrees of permeability, perched water-tables are to be expected.

Isolated wells.—In areas where isolated or very widely spread wells occur it may not be possible to construct either contours or sections of the water-table (even if present); yet the original geological details, and subsequent continuous pumping records, will be useful guides to estimating prospects for future boreholes in the neighbourhood. Their value will increase as more and more wells are sunk.

Springs and wet-lines.—All springs should be marked down and gauged consistently. They are the headwaters or subsidiaries of surface streams fed from underground storage and occur (1) as overflows from permeable rocks at positions where the water-table cuts the surface of the ground—as in the Bunter Sandstone area of Sherwood Forest, or in Chalk districts, where also ' bournes ' commence to flow when the water-table rises above a certain level; (2) as isolated and unrelated issues from irregular systems of fissures in less permeable rocks. As a rule springs are much more regular in yield than the streams they help to feed, and, like rivers issuing from lakes, far less liable to rapid fluctuations.

It may be noted that geologists frequently discover previously unmapped springs, especially alongside, and in the beds of, streams during low-water periods. They also note and usually map ' wet-lines ' or lines of seepage—the potential sources of springs—and relate them to the local geology.

Data of this kind are extremely valuable when local water supplies or impounding schemes are in question, and are especially desirable in districts—such as those of predominantly shaly, slaty or granitic rocks—where no water-table, in the ordinary sense, is to be expected.

Quality of water (mineral).—A point that requires research is that of the potability of water apart from the effects of organic pollution. In certain cases waters in formation near outcrop, and for a short distance beneath cover, are potable, but become increasingly hard, saline, and unpotable

some distance down-dip—yet still well inland, as at Lincoln (Boultham). In other cases sea-water may gain access to concealed water-bearing rocks near the coasts or in estuaries—as in parts of Essex, Kent and Sussex. It is required to discover the approximate line at which the water becomes unpotable, and the underlying causes of the change. Help from geophysicists may be obtained in future, for already it is thought by some to be possible to detect the change from fresh to saline waters in buried rocks by means of instruments. Again, changes in the mineral content of water, where permanent pumping machinery has been in action for many years, are apt to recur *pari passu* with lessening yield. Quite apart from changes that may occur as the distance increases down-dip, or as the overlying geological cover may alter in character (e.g. in some Chalk areas), research is needed on the relative qualities of waters derived from definite individual strata. These ought to be studied much as a palæontologist concentrates on fossil zones. The form of mineral analyses of waters seems to require standardisation so that rapid comparisons may be made. It frequently happens that a bore taps two or three water-bearing horizons, and the analysis made is that of a mixed water. One of the sources, from a particular bed, may be known from previous research to be highly saline. If located and tubed off the quality of the remainder would be improved.

Other problems for study.—Amongst other problems to be studied are (*a*) the prevention of pollution of underground waters by sewage and soakaway, (*b*) the possible repletion of underground reservoirs by means of dumb-wells, (*c*) the effects of mining on the distribution of underground waters.

Conclusion.—Records as complete as possible should be secured of all new wells or borings, and studied from every point of view. Such work can be undertaken only by persons with special qualifications as hydrogeologists.

2. Outline of the Recording and Assembly of Data.

Continuous Measurements of Water Levels.

Records of water levels during static periods or whilst pumping is in progress are kept at the larger water undertakings in the country and occasionally also at private wells (see Appendices (*a*), (*b*), (*c*), (*d*)), some covering as much as eighty years ; but few of these (apart from those within the orbit of any economic unit) have been brought into regular and continuous relationship with others outside, although several undertakings may draw water from the same geological formation in the same drainage area. Hence the regular construction of maps or diagrams showing the (say, monthly) variations in the water-table has been impracticable hitherto. Useful maps and diagrams and empirical rules as to fluctuations to be expected have indeed been issued from time to time in printed papers or water supply memoirs (see Appendices (*d*) and (*e*) and Bibliography) ; but usually the maps refer to only one or perhaps two isolated periods in any one year, or to a mean annual level alone.

An excellent summary of the kind of observations that might be and frequently are taken at pumping stations and private wells will be found in the *Report on Stream Flow and Underground Water Records*, Section II, C and E, issued by the Committee of the Institution of Water Engineers (October 1929), under the chairmanship of Dr. H. Lapworth.

Flow from springs could be measured by weirs.

Collection of general water-supply data.—With regard to the collection of widespread geological and water-supply data derived from the sinking

of borings and wells and the study of springs, those of the Geological Survey are doubtless the most extensive, and may be referred to here as showing the uses to which such collections may be put. Most of the large boring and exploration firms and many water engineers and consulting geologists have considerable, but naturally less extensive, collections of their own, that have been drawn upon for useful publication from time to time.

Geological Survey: water supply data.—Throughout its existence, now nearly a century, the Geological Survey has collected records of well-sections and borings; but in the early days their use was in the main purely geological, as an aid to stratigraphy and mapping. Later, when the value of geological knowledge for underground water-supply became generally recognised, they were sought for this purpose also.

The information, formerly assembled or published in connection with the Old Series 1-in. Geological Maps, was next filed under counties, and the issue of special County Water-Supply Memoirs was begun. This policy has been continued to the present day and twenty-six memoirs have been published. There are also chapters on water-supply in many of the Sheet Memoirs. Data for the early memoirs were gathered from various sources, but the exact siting of a number of the bores left much to be desired, and the other information was, in many cases, all too meagre.

At present the collection, filing and siting of records, which already amount to many thousands, is more consistent, and special studies of areas of underground water-supply are made from time to time.

Details of wells or bores are entered on section sheets with a special heading (Geological Survey Memoir form), and comprise as many observations of a general nature as are likely to be of value—failing continuous observations of water-levels; but it must be noted that the information received is usually incomplete, since the only powers exercised by the Geological Survey are in respect of borings and shafts over 100 ft. in depth, sunk in search of minerals.

Present sources of information are from:—

(1) Old Survey Memoirs and other geological publications.
(2) Information obtained on the spot during the 6-in. surveys now in hand, or from special limited surveys for Water-Supply Memoirs.
(3) Well-sinkers, owners and others who apply for geological advice on water-supply, or who consult the Survey whilst their work is in progress.
(4) The books and files of well-known water-boring firms.
(5) The Ministry of Health, who forward copies of the records supplied to them in cases with which they deal. In important instances the Survey is asked to give an opinion upon the geological aspects of the schemes submitted and the prospects for finding the required amount or quality of water.

With regard to source (3), inquiries about water prospects are now followed up, after a reasonable interval, if the inquirers do not communicate further. As a result, the Survey files are becoming increasingly ample, and a greater number of essential details are secured. In particular, the accurate location of the well or bore is asked for, and this is plotted on a 1-in. map reserved for the purpose.

Inquiries about water-supply dealt with at headquarters in London, Edinburgh, Manchester, York and Newcastle, amount to several hundreds a year.

As a result, the Survey is generally in a position, when inquiries are made about an area, to give a reasonable or accurate estimate of water

prospects; and this power is increasing with time. Furthermore, the geologists become specialists on those areas with which they are best acquainted, from having surveyed and studied either the actual rocks in question, or their counterparts.

Questions of water-supply apart, it is incumbent upon the Survey, as it always will be, to collect as many records as possible of strata pierced by wells, boreholes or shafts, and to secure important rock specimens and fossils for study.

Although much has been done in the past, and more is contemplated for the future, it is not claimed that the organisation is as good as it might be, and this for two main reasons:—

(1) The information has chiefly to be acquired (i) by willing acquiescence or gratuitous offers on the part of water engineers, well-sinkers, and others who appreciate the work that is being done; (ii) by personal relationship between them and Survey officers; or (iii) by the following up of inquiries.

(2) The work is necessarily limited by the time and energies of the staff that can be spared from carrying on the general work of the Survey.

Examples of Connected Records of Water Levels, etc., published in Geological Survey Memoirs.

Water Supply in Nottinghamshire, 1914.—Contours, at 5-ft. intervals, of the water-table in a part of the Bunter Pebble Beds, south of Bawtry and west and south-west of Retford (Fig. 1, p. 7). From one series of measurements only. The concealed surface of the Pebble Beds is contoured (Plate I). This shows the depth with reference to Ordnance Datum at which artesian Bunter waters can be struck beneath impervious Keuper.

Saffron Walden Memoir, 1932 (*Explanation of Sheet* 205).—Contours, at 25-ft. intervals, of the water-table in the Chalk, for February 1928 and June and October 1929 (Plates IV and V). Plotted from measurements made by Cambridge geologists under Mr. W. B. R. King, O.B.E., M.A., and by officers of the Royal Engineers, under Major R. S. Rait-Kerr, R.E.

Wells and Springs of Sussex, 1928.—Map and diagrams of the summit of the water-table in the South Downs, near Brighton, by Mr. A. B. Cathcart, M.Inst.C.E. (Fig. 5); and graphs showing the relationship of water-level in a well at Broadwater, Worthing, to rainfall from drawings by Mr. F. Roberts, M.Inst.C.E. (Fig. 6).

Records of London Wells, 1913.—Contours of the underground water surface at various dates (Fig. 2), and a coloured map of underground water-levels at 25-ft. intervals (Plate I). Also a diagram showing difference in amount of bourne-flow water passing Kenley and Purley gauges (Fig. 4), and a map of the London districts showing contours of the pre-Tertiary Chalk surface.

Appendix *E* (*a*).

WATER LEVEL IN THE CHALK AT COMPTON, W. SUSSEX.

By D. Halton Thomson.

Measured in well at Compton House, Compton. Ground level, 266 ft. O.D. Depth of well, 180 ft. Recorded water level varies between 220 and 94 ft. O.D. No pumping.

The saturation level in the chalk emerges at ground level at varying points lower down the valley up to a distance of 4½ miles from Compton,

according to rainfall and season. This intermittent stream forms the upper reaches of the River Ems.

Weekly water levels are available from 1893 to 1930, and the record is still being maintained (February 1933); there are, however, gaps in the record prior to 1898. Also, prior to 1903, the measurements were made at another well in the near vicinity.

Rainfall records at the same site are available for the whole period; also, since 1920, a percolation gauge, recording percolation through 3 ft. of chalk, has been maintained.

An examination of the well-record shows that during dry periods there is, at any given level, a maximum rate at which that level falls, and that this maximum rate decreases as the level itself decreases. By piecing together these maximum rates a 'dry weather depletion curve' can be established; when the observed rate of depletion is less than that shown by the curve, or if the level is actually rising, the difference is ascribed to percolation: The curve, therefore, can be used to analyse the record into two components, (1) depletion by underflow, and (2) replenishment by percolation. It is also found that there is a direct relation between the vertical displacement of the ground-water level and the effective percolation, by means of which the fluctuations can be converted into rainfall units.

The water levels are normally lowest in the late autumn, when percolation is negligible. If the record is divided into periods of nine to fifteen months, according to the date of recommencement of the annual percolation cycle, it is found that the percolation figures, as measured by the subsoil gauge and as calculated from the water levels, are in close agreement. It is also found that the annual evaporation loss, after excluding the effect of ground-storage, is nearly constant.

Appendix *E* (*b*).

THE SOUTH STAFFORDSHIRE WATERWORKS COMPANY.

Description of Methods for obtaining Water Levels in Wells and Boreholes.

By F. J. Dixon.

In the case of shallow wells the water level is usually obtained by direct measurement with a wooden float and cord, or if permanant apparatus is desired then a copper float with a flexible metallic cord working through either pulleys or geared reducing apparatus indicates the water level.

The actual indication at the surface can be shown on a graduated gauge board or a dial, but if a permanent record is desired then a recorder in which the movement of the chart is synchronised with a clock is the best. Usually these recorders are made to give a seven-day record, but a shorter or longer period chart can be used if the recorder gears are arranged to suit.

For deep wells float gears are not so suitable and in boreholes their use is impracticable. The two most suitable methods are the direct measurement method by galvanometer and the pneumatic system reading either on a gauge or recorder.

The galvanometer consists of a rubber-covered single or double core cable on a drum fitted with handle for winding up the cable. At the loose end of the cable is a sinker with brass contact, which is connected to the cable and covered with a vulcanite sheath, having a hole in the bottom and a small vent hole at the level of the contact. In the case of the double-core

cable, there are two contacts and this sheath prevents the instrument giving a false reading if water from the strata is falling down the borehole. Suitably arranged in a box with the cable drum, are a milliameter and a 9-volt dry battery. In the case of the single core cable the circuit is completed by earthing on to the pump or by a copper bar pushed direct into the ground. To obtain the water level the cable is lowered until the pointer of the milliameter is deflected, showing contact has been made at the water level when the cable is drawn up and the level determined by measurement.

The pneumatic system consists of a gauge or recorder, mounted usually with the pump gauges, together with an air bottle with pressure gauge, control cocks, foot pump and copper-piping carried down the borehole below the lowest water level.

The piping (¼-in. bore) is clamped to the pump and lowered with it as erection proceeds. If the size of the borehole will allow, then a bell is usually placed on the end of the pipe to act as a small air reservoir.

The gauge or recorder is connected direct on to the pipe and a branch on the pipe connects to the air bottle, which is turn is connected to the foot pump. A control valve is placed directly under the gauge and also on the pipe leading from the air bottle. The gauge or recorder is graduated in feet below floor level, but the dial is reversed as regards marking when compared with a standard gauge. Assume the gauge or recorder was to read to a maximum depth of 200 ft. below floor level, then the end of the pipe or bell must be exactly this distance below the floor. If the water was down to this level there would be no pressure in the pipe and the pointer in its zero position would show 200 ft. on the dial or chart. It is necessary to maintain a pressure in the air bottle higher than pressure due to variations in water level and a gauge is fitted on the air bottles to enable the operator to see he is maintaining a suitable pressure with the foot pump.

If we now assume the water level is 100 ft. below floor level and the pressure in the bottle was 90 lb., then the air admitted to the gauge pipe would leak away at the bell or pipe end until the pressure just balanced the head of water in the borehole and the pointer would now show 100 ft. below floor level on the gauge or recorder. Where there are marked variations in water level due to alterations in the rate of pumping, or the plant is only operating a certain number of hours daily, then the best instrument to instal is the seven-day recorder type, as every alteration is indicated and the actual time when it occurred, the charts thus obtained giving valuable permanent records.

A galvanometer is usually provided at each station to check the pneumatic depth recorder and also for use in case of a failure on the air-pressure system.

Appendix *E* (*c*).

1. PUMPING TESTS AT NEW BORINGS FOR WATER.

2. GAUGING OVER LONG PERIODS FROM WELLS IN THE CHALK.

By R. C. S. Walters.

1. New Waterworks, Ashbourne, Derbyshire, 1930.

The water is from Bunter beds lying 223–300 ft. below surface, and beneath Keuper Sandstones and Marls. Borings consisted of a trial bore and two permanent boreholes.

In May 1926 the trial hole was tested. This hole was 8 in. in diameter and 300 ft. deep, and was found to justify the development of the site.

By January 1927 the first of two permanent boreholes, 32 ft. apart, each 23 ins. diameter and 300 ft. deep had been sunk and tested. The second permanent boring was sunk and tested by the following July. The trial boring was 5 ft. distant from No. 1 borehole and 31 ft. from No. 2 borehole.

The table below summarises these tests.

The great variation in tests may be traced mainly to the effect of opening out the strata by several borings and also the result of clearing by extended pumping. It is obvious that in such strata any conclusions as to the true yield can only be arrived at after many tests or prolonged pumping.

Summary of Tests on Boreholes.

Duration One to Five Days.

Test.	Date.	Hole.	Quantity Gals. per hour.	Rest Level Feet.	Lowering Feet.	Specific yield. Gals. per hour per foot.
1	May 1926 .	trial	4,840	25	43	110
3	January 1927 .	No. 1	10,500	26	70	150
6	February 1927 .	No. 1	10,000	28	44	227
8	July 1927 . .	No. 2	15,500	25	113	138
9	January 1929 .	No. 2	12,500	29	59	212
10	January 1929 .	No. 1	12,500	29	44	284

2. A summary of the facts concerning wells in the Chalk which have been gauged for continuous long periods—varying from a minimum of three to a maximum of eighty-four years—will be found in Table I of 'The Hydro-Geology of the Chalk of England,' *Trans. Inst. Water Engineers*, vol. xxxiv, 1929.

Appendix *E* (*d*).

NOTES ON RAINFALL, REST-LEVELS AND PUMPING LEVELS IN THE CHALK

as deduced from records supplied by

A. E. Cornewall-Walker.

The East Surrey Water Company.

The records consist of graphs, for 1924 to 1930 (inclusive), at the Purley Well, of (*a*) Rest Level ; (*b*) Pumping Level, and (*c*) Rainfall.

From a study of the graphs the following points emerge :—

(1) The low degree of porosity is shown by the way in which the rise of the water level lags some four months behind periods of heavy rainfall.

(2) Irregularities in the rainfall curve tend to become smoothed out in the rest-level curve ; thus, at one point, two 'peaks' in the former produce one in the latter.

(3) After long periods of heavy rainfall the water-level remains high for a

considerable period, the curve being flat-topped ; while after short periods of heavy rainfall the high water-level soon drops, giving pointed curves.

(4) The average curve of pumping-levels follows closely the curve of rest-levels. In the present case a composite pumping-level curve is shown, stronger pumps having been installed in 1926. A measure of water pumped is shown by the difference in feet between the two water-level curves ; and the stronger pumps increase this difference without otherwise affecting the similarity of the two curves. From this illustration it is seen that in wells where it is not possible to measure rest-levels, except at very long intervals, some idea of the rest-level may be obtained if records of pumping-levels are kept, and the difference between pumping and rest-levels, as determined by occasional measurement, added.

(5) Compare—

(*a*) 'London Wells' (*Mem. Geol. Surv.*), Plate III.
(*b*) 'Wells and Springs of Sussex' (*Mem. Geol. Surv.*), pp. 19–20.
(*c*) 'Hydrogeological Conditions in the Chalk at Compton, Sussex,' *Inst. Water Engineers*, 1921.
(*d*) *British Rainfall*, 1919, pp. 257–262, for summary of details, and bibliography, of records from 1836 onwards, for Chilgrove.

Main Memorandum *F*.

RIVER GAUGING.

By W. N. McClean.

1. Choice of Sites.

The sites generally chosen by river authorities for gauging rivers are at weirs which have been constructed for the purpose of abstracting water or controlling flow. These sites are chosen because, by installing a recorder water level gauge in still water above the weir, the flow at any water level is given by some weir formula. That there is any resemblance to accuracy during floods seems to be unlikely. For low flow estimates they may be very convenient.

In practice, the weir itself is not the weir of the laboratory experiment ; except at low flows, it is partially or wholly submerged and a varying formula has to be used according to the downstream water levels at some vague point. The velocity of approach is probably unmeasured. Records of the water abstracted, which may be the greater part of the low flow, have to be kept accurately. There are often many complications of sluice control.

Generally speaking, the best site for river gauging, with the current meter, is a steady-running reach with a steeper water slope down stream, so that there may be no backing up due to the downstream flood conditions.

These sites are not always obtainable, and often the water-slopes on rising and falling rivers will have to be very carefully measured during the gaugings and afterwards for the records.

Sites should be chosen where the river is always within its banks or where the overflow is never of any considerable amount.

The choice of a site for gauging is not often an easy matter and it may be necessary to use different sites for floods and low waters. There is much to be said for the reading of low flows at weirs or in narrow channels and the big wide reaches are best for floods.

The main object of gauging a river should be to obtain continuous records of water level and of corresponding flow.

2. Site Survey and Water Level Gauge Installation.

Assume that a suitable site has been selected.

A careful survey of the river bed and banks should be made above and below the gauging section. The zero for levels and the zero and direction of the gauging section should be fixed, for all time, by permanent stations on the banks which are included in the survey.

The sites of the water level recording points have then to be settled. One of these will have to be the final station for the continuous records of water level. Another will have to be on the gauging site in order to give the depths of water during the gaugings. This will have to be a permanent gauge if the water slopes are found to differ on the rising and falling river.

The water level apparatus requires special consideration according to the nature of the site, but automatic recorders and gauge posts are necessary.

When sufficient funds are available there is little difficulty in setting up permanent stations with float gauges; but in the more ordinary circumstances it is best to follow the bank up with short gauge posts or with a series of pipe-wells for the use of a hook-gauge. The automatic takes the form of an air box in the lower well connected by a small diameter pipe to the clock-driven chart on the bank top.

The site may now be considered as equipped with the necessary water level apparatus for the flow measurements and for the permanent records.

3. Flow Gauging Apparatus, its Setting-up and Use.

On rivers of any considerable width where floods are to be measured, the apparatus is the boat or punt or double-punt, with a cross river ropeway; the velocities being measured by current meters on wire or rod. The writer and others have used the bos'n's chair on a ropeway, and it is not satisfactory. A portable bridge with trestle piers on the lower part of the bank may prove best on narrower rivers.

In the writer's experience, accuracy of current meter observations is dependent principally on the use of a rod which holds the current meter steady to the point and depth; readings then become uniform, even in the presence of considerable turbulence.

The writer's apparatus has been developed gradually. It is founded on a secure ropeway across the river which remains unchanged throughout the whole period of gauging work. It is easily transported, and is adaptable to most sites. The head lines of the double-punt are attached to a small trolley which is made to travel along the ropeway by means of an endless rope worked from a winch on the bank. The double-punt is steadied and held in position by another light wire rope across the river. This rope passes round a drum fixed at the base of the frame which holds the gauging rod, and the strain on the rope is regulated from the bank. An independent tally line marked at each 5 ft. is permanently stretched across the river about 2 ft. upstream of the actual gauging section.

The double-punt used by the writer is very completely equipped for control from a small cabin. The operations are :—

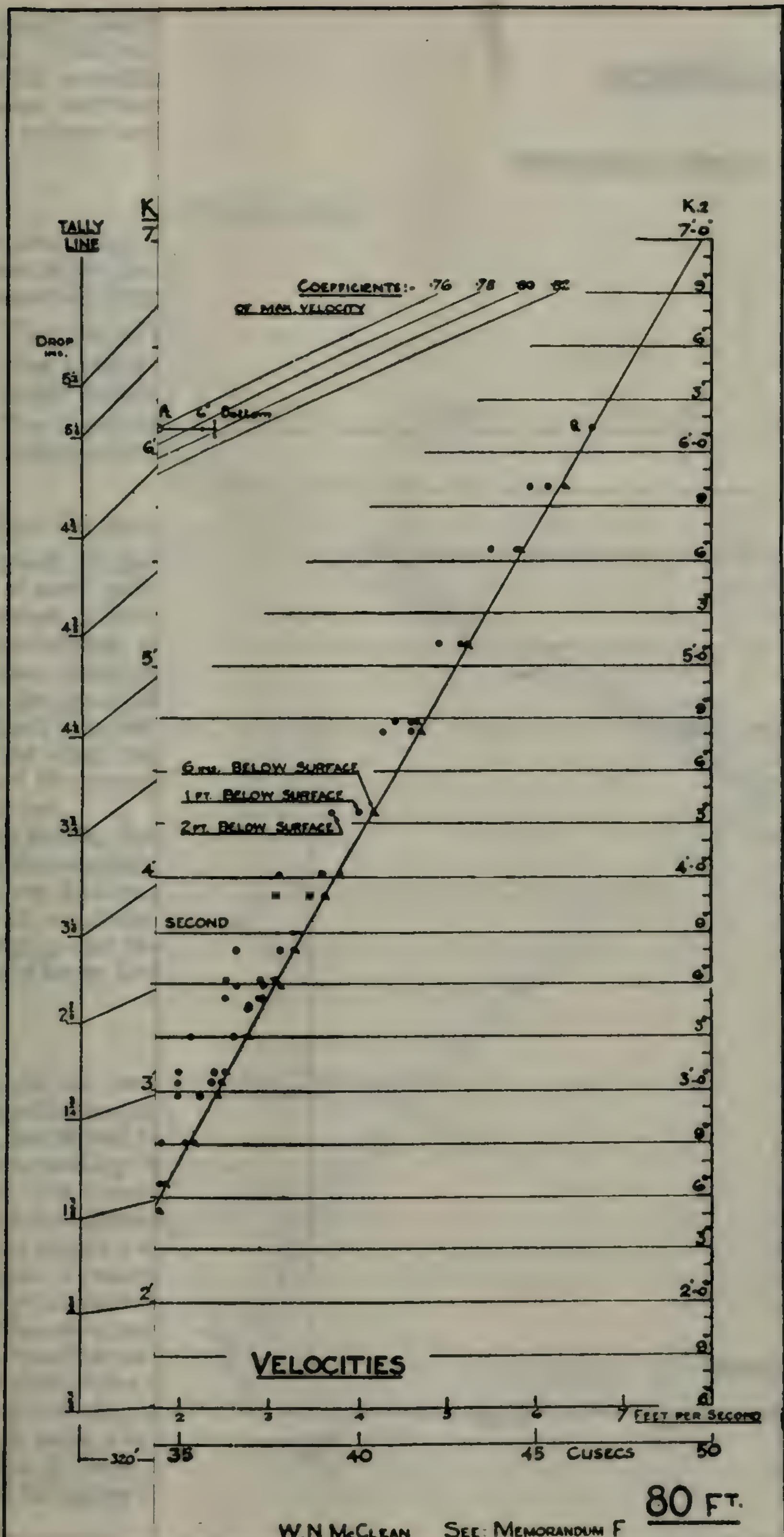
(1) Adjustment up and down stream on the head lines.

(2) Adjustment to the tally line mark by revolving the drum of the straining rope.

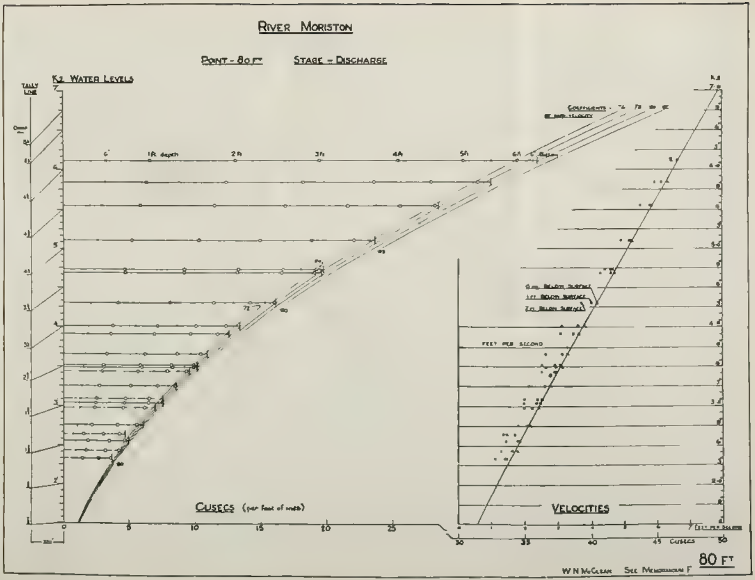
(3) Adjustment of the current meter depth by raising or lowering the rod.

Each punt is in two parts for ease of transport and launching.

The principal point to emphasise is the use of the streamlined rod, which


TALLY LINE
K.2
7'·0"
COEFFICIENTS:- ·76 ·78 ·80 ·82
OF MEAN VELOCITY
DROP INS.
6 INS. BELOW SURFACE
1 FT. BELOW SURFACE
2 FT. BELOW SURFACE
SECOND
VELOCITIES
FEET PER SECOND
CUSECS
35
40
45
50
320'
80 FT.
W.N McCLEAN SEE: MEMORANDUM F

[To face p. 422.


River Moriston
Point - 80 ft
Stage - Discharge
K2 Water Levels
Tally Line
Coefficients
Cusecs (per foot of width)
Feet per second
Velocities
0.6ft below surface
1 ft below surface
2 ft below surface
Cusecs
Feet per second
80 FT
W N McClean See Memorandum F

[To face p. 450.

enables steady observations to be made at depths of 17 ft. or over in high velocities. This rod resembles the struts of an aeroplane in section. It is also used for soundings. The efficient and safe carrying out of the gauging is dependent on the care, skill, and accuracy of a surveyor, who is a practical engineer, a rigger and a boatman.

4. Current Meters.

There are many good types of meters which record, electrically, the revolutions of the meter.

The essential gauging points are :—

(*a*) The care of the meters.

(*b*) The careful work of looking out for weeds, leaves, etc., on the meter during gauging.

(*c*) The frequent calibration of the meters at the National Physical Laboratory and the use of several meters.

5. The Gauging Operations and accompanying Field Work.

On a 100-ft. to 300-ft. width of river, the velocities are measured on every gauging at each 10-ft. mark on the tally line, and often at every intermediate 5 ft. At each of these points, velocities are measured at 6 in., 1 ft., and each foot to the bottom, and at intermediate 6 in. near the bottom.

The time intervals given by the buzzer are entered on the field sheets, and also the clock time at the point.

On shore, the assistant keeps the water level records at the two gauges against the clock time. A hook-gauge in a well is used for these water levels, and they are plotted for the day. Automatic recorders may be used in the future.

During floods, the water levels vary very considerably during the gauging day, but the underlying principle of the writer's method is that each point on the river has its separate stage-discharge curve, thus eliminating inaccuracies of computation due to varying water level during the gauging day. The gauging day thus ends with velocity field sheets and the graphs and readings of water levels.

6. Computations.

These do not need description in detail, and the whole work centres on the Stage-Discharge Diagram at each gauging point on the section. A diagram is attached to this Memorandum, giving, for each water level gauged, the cusecs passing the point for a 1-ft. width of river and, by intermediate markings, the cusecs passing at each foot or 6 in. of depth. The water slope is given against the water-level height of the recorder gauge. To this diagram is added a diagram of maximum velocities at and near the surface. This yields a maximum velocity-stage graph, and, by applying different coefficients to these maximum velocities, the coefficients applicable to each stage of the river may be judged.

These coefficients are used for the final smoothing of the stage-discharge curve of each point, and, finally, the discharges at each 3 in. of water level height are transferred to a diagram giving the discharges for the whole river section at each 3 in. of water level. The results are also tabulated. On these lines, if there is no overflow, the discharge values may be reasonably extended to higher floods and approximately to lower low waters.

7. The Continuous Record of Water Levels converted into Flow Records.

There is, firstly, the table of flow for each ½ in. or so of water level, which has resulted from the river gaugings.

From the graph of the water level recorder, the average water level of each 3 hours is tabulated on the main records table and each 3-hourly value is converted into flow. The daily average flow is then tabulated.

On special floods, shorter time intervals may be used on a similar table. Such tables will provide all necessary data for any investigation required.

The essential point to make clear is that the records should be, firstly, records of water level and the conversion to flow should not be made on the water level recorder graph. The reasons for this decision are many. The shortest way of putting the point is that flow measurements are subsidiary to water-level measurements and that the connection between the two may change (1) by changes in the river, and (2) by improved measurements. But beyond that, water levels are a definite record of storage and stage throughout the whole river system.

In further reference to river gauging, extracts from Prof. Dixon's and Mr. Griffiths' statements are attached (see Appendices *a* and *b*).

Appendix *F* (*a*).

NOTES ON THE GAUGING OF THE RIVER SEVERN, AT BEWDLEY.

By S. M. Dixon.

1. The gauging site, half a mile above Bewdley Bridge, is in a section of the river which is sensibly straight and of reasonably uniform width for a little over three-quarters of a mile. About a quarter of a mile above the site is a short section of rapids, which dries partially at extreme low flows. Another similar shallow section occurs three-quarters of a mile below the gauging site. The river, near the site, flows between high steep banks, its width varying from about 140 ft., at minimum flow, to about 180 ft., at which point it overflows its banks into level fields on either side. The bottom is of rock, and the depth at minimum flow varies from 7 ft. in midstream to about 3 ft. close to the banks.

There is a gauge post at the site, consisting of four cast iron sections, bolted to steel channels, set in concrete on the bank, each projecting 3 ft. from the ground, and recording over a total rise of 11 ft. in water level. Each foot is divided into tenths.

Daily records of the water level are read on a permanent cast iron scale fixed just below Bewdley Bridge, about half a mile down-stream of the gauging site, and on a sloping concrete scale cut in the Aqueduct carrying the Birmingham Corporation's water supply across the river two miles above the site. An automatic recording gauge is also installed at the latter place and is attended to weekly by the Corporation Water Department's walksman, who lives close by. The sloping concrete scale serves to check the setting of the automatic recorder.

The zero of the gauge at Bewdley Bridge was chosen to correspond with the lowest water level which was likely to occur. The zeros of the other fixed gauges were chosen arbitrarily, the zero of the automatic gauge at the

Aqueduct being the same as that of the fixed gauge beside it. On the Aqueduct gauge the reading of the lowest water-level recorded is 9·4 ft., corresponding to a discharge of 290 cusecs. Other extreme readings are :—

Highest recorded level, 24·5 ft. corresponding to a discharge of 17,000 cusecs.

Highest summer level, 21·7 ft. corresponding to a discharge of 12,400 cusecs.

Lowest winter level, 10·15 ft. corresponding to a discharge of 710 cusecs.

2. Two meters are used for measuring discharges, an Amsler propeller-type meter, and the small Price bucket-type meter. In each case, velocities are measured at intervals of 1 ft. vertically in planes 10 ft. apart horizontally.

The Amsler meter is always used on a rod operated from a flat-bottomed punt. The punt is located and kept stationary by two wire cables, bow and stern, anchored to the banks, and the rod held over the side.

The Price meter is always used suspended from a cable slung between two permanent steel standards fixed on either bank. Raising and lowering and traversing the meter are accomplished by means of two winches, one on either standard. A full description of this apparatus, and of the method of using it, will be found in a paper entitled 'River Gauging' by M. A. Hogan, Ph.D., and published by the Department of Scientific and Industrial Research.

Except close to the banks, and in conditions of extreme low flow, the velocities of water at the gauging site always exceed about $\frac{3}{4}$ ft. per sec., and no attempt is made to measure velocities below $\frac{1}{2}$ ft. per sec.

Occasional measurements of surface velocities are made with wooden floats 3 in. square and 1 in. thick, their paths being determined by readings from two theodolites on the tow-path.

The field book contains five columns, Distance (from a fixed point on bank), Sounding, Depth of Meter, No. of Revolutions (of meter) and Time. The corresponding velocities are subsequently determined from the meter's rating curves—which are checked from time to time in the College Laboratory—and the discharges are worked out graphically, by plotting cross sections of the river and the velocity-depth curves at each 10 ft. vertical. Corrections are applied, if necessary, for alteration of the water-level during gauging, and for down-stream sag of the meter's suspending cable.

Up to the present, some eighty-five gaugings have been made on about fifty different occasions during the last eleven years. It is hoped that it will shortly be possible to compare the results with measurements of the discharge made at Lincomb Weir, some four miles further down the river.

(Diagrams have been made showing the section of the river at the gauging site, a typical annual hydrograph, and a drawing from which the results of a gauging were calculated.)

Appendix *F* (*b*).

THAMES CONSERVANCY.

Notes on Gauging.

By G. J. Griffiths.

Current Meter Gauging.—A straight uniform section of the river is selected, usually 100 ft. in length, and carefully cross-sectioned at both ends and in the middle. Wires are spanned across the river at each cross-section, divided into 10 ft. intervals or compartments.

A current meter (propeller type), with either visible or audible revolution counter, is then submerged at 6 in. and at other regular depths down to a point of 6 in. above the river bed, in the centre of each compartment, readings being taken at each depth. From the plotted velocity curve an average velocity for the compartment is obtained.

This velocity, in feet per minute, is multiplied by the area of the compartment, and the summation of this process for all the compartments gives Q for the length of river in question.

At times the gradient of the river is also taken and a discharge is calculated and compared with the current meter observations, with a view to finding the appropriate coefficients for the section of river under examination. It may be pointed out, however, that this investigation is by no means easy of application on the Thames. The river is weired at average intervals of $2\frac{1}{2}$ to 3 miles, and it is only when the weirs are fully drawn, or nearly so, that an approximately natural condition can be obtained.

Also when the river is in full flood the water overflows the banks and shallow side streams flow over land and meadows which are obstructed by hedges, fences, buildings, etc. These and many other practical difficulties have to be provided for, and it is largely a matter of experience as to the best method to be adopted under the particular conditions of each case.

In certain cases it is found advisable to substitute rod or float readings for current meter observations.

NOTE.

The Report on Inland Water Survey was adopted at the Leicester Meeting of the British Association, 1933, by Sections A (Mathematical and Physical Sciences), E (Geography), and G (Engineering), on whose recommendation the Committee was appointed in 1932. It was felt by these Sections that Memorandum E and its appendices, dealing with the measurement of underground water, should be regarded as a basis for fuller treatment of the subject, after consultation with Section C (Geology).

SECTIONAL TRANSACTIONS.

(For reference to the publication elsewhere of communications entered in the following lists of transactions, see end of volume, preceding index.)

SECTION A.
MATHEMATICAL AND PHYSICAL SCIENCES.

Thursday, September 7.

Prof. L. Vegard.—*The auroral spectrum and the upper atmosphere* (10.0).

A summary account is given of present knowledge of the auroral spectrum and its consequences.

Most of the results are based on spectrographic work carried out in Northern Norway, at Bosekop and Tromsö (1912–26), and during the last three years important results were obtained at the new Auroral Observatory, Tromsö, in collaboration with Mr. L. Harang and Mr. E. Tönsberg.

In the explored region from 9,000 Å. in infra-red to the limit of atmospheric transmission in ultra-violet, 85 bands and lines have been detected. Apart from the strong green line and a couple of red lines, probably due to oxygen, the auroral spectrum is dominated by nitrogen bands belonging to the negative, and the first and second positive, groups. The type of nitrogen spectrum agrees well with the theory of Birkeland, that the luminescence is produced by electric rays from the sun. The high intensity of the green line is explained by assuming oxygen atoms excited through collisions of the second kind with active nitrogen, where a kind of resonance effect takes place.

The auroral spectrum gives no indication of an upper atmospheric layer dominated by hydrogen and helium.

Typical variations within the auroral spectrum have been detected and studied. One of these consists of the enhancement of red lines producing the red colouring of the auroræ. A second is an altitude effect detected in 1923, one aspect of which is the enhancement, with increasing altitude, of the nitrogen bands relative to the green line.

The temperatures of the emitting molecules of the auroral region were quantitatively measured by means of negative nitrogen bands.

The spectral altitude effect, seen in relation to the height, extension and luminescence of the auroral streamers and to the low temperature observed, shows that nitrogen must be carried to high altitudes through the effect of an electric state set up by the action of a solar radiation of short wave-length. The resulting state and the distribution of matter, resembling the sun's corona, is described and shown to fit in with results of radio-echo work, and to give a simple explanation of the zodiacal light and the night-sky luminescence, agreeing well with spectral observations of Rayleigh and Slipher.

Dr. R. J. Van de Graaff.—*The electrostatic generation of high voltage for nuclear research* (10.30).

JOINT DISCUSSION with Section K (Botany) on *The X-ray analysis of fibres* (11.0) :—

Mr. W. T. ASTBURY.—*Some recent developments in the X-ray interpretation of the properties of hair, feathers and other protein structures.*

The recognition by X-ray methods of the regular, side-to-side cohesion of long, chain-like molecules to form crystalline bundles has served to give form to existing physico-chemical data, and helped us to understand for the first time many of their most characteristic properties. In particular, it has been found possible to follow changes under applied stress and chemical treatment of the configuration of gigantic protein molecules, such as those of the keratin of hair and feathers, and thereby to study the molecular mechanism of their long-range elasticity and link it up with that of simpler molecules. The crystal analysis of the chain-bundles involves at the outset some generalisation of the usual geometrical treatment, with the result that we are led to the concept of standard average dimensions of *intra-molecular* units, from which can be predicted the probable density of proteins as a class and the weight per unit area of mono-molecular protein films. Deviations from these standard average dimensions, as in the case of gelatin, may be used to investigate the linkages which give rise to them and ultimately, it may be hoped, to derive the precise form of the intra-molecular pattern, while from a knowledge of the molecular direction associated with each particular dimension we may follow the course of localised reactions such as the attack of water on the protein side-chains. The interaction of water with protein and other chain-bundles offers points of considerable interest, especially when studied in relation with their elastic properties.

Dr. R. D. PRESTON.—*The structure of the cell wall of Valonia.*

While the cells of most species of *Valonia* are approximately isodiametric and are not to be considered as fibres in the morphological sense, their walls are certainly composed of molecular fibres such as are typical of the true fibres of the plant. Sufficient work has already been carried out to indicate the importance of investigations on the walls of these large cells in relation to the organisation of the walls of what may be called the ' obvious ' fibres. The wall of *Valonia* consists of a kind of molecular basket-work over the whole surface composed of two sets of cellulose chains, crossing at about 80° to each other, which have been shown to be parallel to the two sets of striations visible under the microscope. These chains of cellulose exist in the form of well-defined crystalline aggregates whose orientation is usually remarkably perfect. As observed by Sponsler, the planes of spacing 6·1 Å. tend to lie parallel to the surface of the wall, though there exists an undoubted dispersion. Variation of the relative amounts of the two sets of chains from point to point in the wall gives rise to a somewhat misleading heterogeneous appearance in the polarising microscope.

The structure of the cellulose net of the whole wall is now being mapped out by a ' lines of force method,' and it seems highly probable that the crossed chains observed at any point are portions of two spirals.

Dr. J. B. SPEAKMAN.—*Fibre chemistry and X-ray analysis.*

Wool fibres may be stretched as much as 70 per cent. of their length in cold water without losing the power of returning to the original length. If, however, stretched fibres are exposed to the action of steam for, say, six hours, they assume a ' set ' which is not eliminated even by re-steaming

in the absence of tension. The discovery that deaminated fibres are incapable of taking a 'set' permanent to steam, gives an opportunity of interpreting the molecular mechanism of the setting process. The problem is interesting because its solution involves the combined use of chemical and X-ray methods, and because of the many analogies between the action of steam on strained fibres and the heat coagulation of egg albumin.

Mr. J. THEWLIS.—*Fibre structure in teeth.*

X-ray analysis reveals that tooth enamel, like several other growing structures (e.g. asbestos, cellulose), consists of fibres. Tooth enamel consists mainly of calcium, oxygen and phosphorus, with the possible addition of chlorine or fluorine, and the atoms of these elements are arranged in the same way as in the mineral apatite. The crystals of apatite, and hence of enamel, are hexagonal, and the arrangement of the enamel fibres is such that the hexagonal axes of the individual crystallites all tend to be parallel—i.e. the hexagonal axis is the fibre-axis.

In human enamel there are two sets of fibres, one with the fibre-axis inclined at about 20° to the normal to the surface of the tooth, and on the same side as the tip; the other with the fibre-axis inclined at about 10° to the normal to the surface, and on the opposite side to the tip. In dog's enamel the fibre-axis is at right angles to the surface of the tooth.

Variations in degree of fibreing are found in histologically normal enamel, and three kinds of enamel can be distinguished. In human teeth it is found that one kind is associated with clinically immune teeth, and the other two with clinically susceptible teeth.

Mr. OLAF BLOCH.—*Principles and applications of infra-red photography* (12.30).

A photograph of the audience was taken at the beginning of the demonstration, the hall being illuminated with infra-red light.

The renascence of interest in infra-red photography is due to the synthesis of a new tricarbocyanine dyestuff which renders possible the production of emulsions of considerably higher speed to infra-red radiation and greater cleanliness in processing than existed previously.

Much interest has been created by the long-distance photographs in which there has been a considerable amount of haze penetration owing to the lessened scatter of infra-red light by moisture particles constituting haze or mist. But there are many other applications of the process to the arts and sciences, and examples of these are shown and discussed. They include astronomy, medical work, photo-micrography, investigation of dyed materials, spectroscopy, the detection of obliterated, over-written or erased writings. Some of these depend upon the power of infra-red radiation to penetrate beneath the surface of tissues, etc., which are opaque, or nearly so, to visible radiation. In short, since most photography is record work depending upon differentiation, wherever differences exist between the infra-red photograph and the ordinary photograph, the process is one which may have a useful application.

AFTERNOON.

Excursion to Daventry Broadcasting Station.

Friday, September 8.

PRESIDENTIAL ADDRESS by Sir G. T. WALKER, C.S.I., F.R.S., on *Seasonal weather and its prediction* (10.0). (See p. 25.)

Prof. F. LINKE.—*The influence of the stratosphere on cyclone formation* (11.0).

The Norwegian polar-front theory stands in contradiction to the opinion of several German and Austrian meteorologists, in that the formation and movement of cyclones are produced by inertia or gravitational waves in the stratosphere.

The wave movements originating on the fronts of the troposphere are insufficient to explain the energy produced thereby.

The following facts speak for independent stratospherical waves :

(1) On all stratifications with sufficiently great density gradients inertia-waves can originate, therefore also in the tropopause.

(2) By means of isallobar maps one can study the course of very expansive wave systems right round the earth, which do not agree with the movements of the cyclones and even intersect them. These wave systems must have their origin in the stratosphere. It is observed that fronts which are becoming stationary again become activised by such waves.

(3) According to the Norwegian view, on the ground, cooling must be connected with rising air pressure and decrease of cloudiness, warming with falling air pressure and increase of cloudiness. Frequently, however, especially in the middle latitudes, a rise of pressure is observed with warm air invasions, and a fall of pressure with cold air invasions. This can only be explained by means of the overlying stratospherical waves.

(4) Persistent obviously stratospherical high pressures and low pressures are sometimes observed. These are circumscribed by short stratospherical waves, which can invite the building of cyclones.

The stratosphere therefore controls the tropospherical cyclones. ' Fronts ' are stimulated when energy is supplied to them through alterations of the pressure gradient, which are determined in the stratosphere.

On the other hand, however, a reaction of the occurrences in the troposphere on the stratosphere also takes place. This must be explained on purely dynamical lines, whereas the action of the stratosphere is purely statical. There exists, therefore, a mutual coupling between stratosphere and troposphere. The Norwegian and German-Austrian cyclone theories are united in a ' theory of the complex cyclone,' whose further investigation constitutes the chief problem of synoptical meteorology.

Prof. E. REGENER.—*New results in cosmic ray measurements* (11.25).

Mr. WM. TAYLOR, O.B.E., and Mr. H. W. LEE.—*The development of photographic lenses at Leicester* (11.50).

The problem of the photographic lens is to secure a well-defined image over a considerable flat field. The solution was not discovered till dense barium crown and light flint glasses were available to the lens designer, although the principles applied by Dennis Taylor in the Cooke lens could have provided a solution with the older glasses. Rudolph (1890), Goerz (Dec. 1892), and H. Dennis Taylor (Jan. 1893) solved the problem, in different ways, with the aid of these. The Continental type of lens,

comprising many components cemented together, is compared with the Cooke lens in its various types.

For aerial photography during the war a special type of lens was required, and the Cooke-Aviar was developed. At this time also the aperture of the Cooke was increased to F/3. In recent times still larger apertures have been called for, and the Cooke F/2 and F/2·5 and F/1·5 lenses developed. Projection lenses for the modern cinema also have had to be of greater aperture, and this has led to the development of a series of lenses of apertures F/2 to F/1·5. It is noteworthy that all the modern large-aperture lenses consist, like the Cooke lens, of separated components, and that the Continental lens, with many components cemented together, has practically dropped out in the race.

The anastigmatic Telephoto lens was also first made at Leicester.

The problems of optical design, and the methods used, are reviewed.

The trend of photographic optics is towards the production of lenses of small focal length and greater speed, largely influenced by the increasing employment of small cameras, kinematographs, and finer grained emulsions.

Leicester methods of manufacture and testing lenses. Interchangeable manufacture.

Dr. L. Simons and Mr. E. H. Smart.—*Demonstration of a model to illustrate the classical motion of a diatomic rotator with two degrees of freedom* (12.40).

Afternoon.

Visit to British Thomson-Houston Works, Rugby.

Monday, September 11.

Discussion on *Atomic transmutation* :—

Rt. Hon. Lord Rutherford of Nelson, O.M., F.R.S.—*A review of a quarter of a century's work on atomic transmutation* (10.0).

In 1907 a discussion on the constitution of the atom was held before Section A at the meeting of the British Association at Leicester, in which the importance of the study of the transformations of radioactive bodies was indicated, and the difficulty of explaining the part played by positive electricity was emphasised.

In 1911 clear evidence for the nuclear structure of the atom was put forward. It soon became evident that outer electrons played no major part in transmutations, and that in order to institute any permanent atomic transmutation the structure of the nucleus must be changed. In 1919 decisive experiments were made. When α-particles were fired in nitrogen, a new type of particle appeared—the *proton*. Photographic evidence showed that the *capture* of an α-particle by the nucleus was accompanied by the *emission* of a proton. The nitrogen nucleus, therefore, of mass 14 and charge 7, assimilates an α-particle of mass 4 and charge 2 and expels a proton of mass 1 and charge 1. We are therefore left with a nuclear structure of mass 17 and charge 8, which is an isotope of oxygen. Other transmutations may be similarly checked, remembering that all such changes must obey what may be termed *general* energy conditions.

Beryllium of mass 9 and charge 4, when bombarded, captures an α-particle of mass 4 and charge 2, giving rise to a nucleus of mass 12 and charge 6,

emitting a *neutron* of mass 1 and charge zero. Future experiments will show that the neutron is a very powerful weapon of research.

Five years ago it became evident that other types of fast particle must be used if more information were to be forthcoming, and it was found possible to obtain from the electric discharge large supplies of particles the speeds of which might be raised by passage through an electric field. This demand has resulted in the development of laboratory methods for the production of high potentials.

Lately, developments of wave mechanics theory have shown that particles which could not normally surmount a potential barrier might yet get through if intense streams were employed at relatively low voltages.

Dr. J. D. Cockcroft and Dr. E. T. S. Walton.—*The transmutation of elements by high velocity protons* (10.30).

The production of types of nuclear transmutation other than the classical α-particle-proton synthesis by Rutherford and Chadwick was for many years considered to require ions of several million volts energy for use as projectiles. This deterrent was removed by the new view of atomic collisions introduced by the wave mechanics, Gamow's theory of the nucleus suggesting that protons having energies of a few hundred thousand volts ought to be able to penetrate the nuclei of the lighter elements.

The apparatus developed by the authors produces protons having energies up to 700 kilovolts ; with these protons they have been able with certainty to disintegrate the elements lithium, boron and fluorine, the entry of the proton leading in all three cases to the ejection of an α-particle. Lithium splits up into two α-particles, two types of transmutation occurring in one of which an energy equivalent of 17 million volts is liberated. Boron appears to split up into three α-particles with a total energy release of about 9 million volts. Wilson chamber photographs of the disintegration processes are shown, and the evidence for the conservation of energy and momentum discussed. The relations between the Gamow theory and the experimental results are considered.

Dr. M. L. Oliphant.—*The disintegration of the elements with hydrogen ions at low bombarding energies* (11.0).

Experiments are described in which many of the elements in a very pure state have been bombarded with protons and with ions of the hydrogen isotope of mass 2. It is shown that the heavy elements, and in particular lead and uranium, are not disintegrated appreciably by bombardment at energies below 220 kilovolts. The extraordinary sensitivity to traces of boron and lithium are described.

The disintegration of boron by proton bombardment is discussed in detail, and the results obtained are explained tentatively by a simple theory.

The disintegration of lithium by both protons and ' deutons ' is described, and the remarkable efficiency of the latter particle as a disintegrating agent is pointed out.

Mr. P. I. Dee.—*A photographic investigation of the transmutation of the elements* (11.30).

The experimental methods used in the investigation of the transmutation of the light elements, as described by the earlier speakers, have been extended by the construction of an expansion chamber to work in conjunc-

tion with the high voltage apparatus of Cockcroft and Walton. The beam of high velocity ions was directed upon a thin target of the element under investigation, contained in an evacuated tube which passed through the glass roof of the expansion chamber. The walls of this tube where they surrounded the target were constructed of mica of such thickness that the disintegration particles passed through them and formed cloud tracks which ended in the chamber, whilst any protons scattered at the target were completely absorbed in the mica.

With a target of lithium subjected to proton bombardment under these conditions photographs were obtained which showed the emission in opposite directions of pairs of particles, each of range 8·3 cm. This would correspond to the mode of transmutation given by the equation

$$_3Li^7 + {}_1H^1 \rightarrow {}_2He^4 + {}_2He^4.$$

Photographs showing a similar emission of pairs of oppositely directed particles were obtained when lithium was bombarded by ions of the heavy isotope of hydrogen, but in this case each particle had a range of 13·4 cm. This would correspond with transmutation according to the equation

$$_3Li^6 + {}_1H^2 \rightarrow {}_2He^4 + {}_2He^4.$$

The ranges of the helium atoms obtained by substitution of the exact atomic masses in these equations are 8·4 cm. and 13·0 cm., agreeing closely with the observed values.

Photographs of the short range particles produced when lithium and boron are bombarded by protons have also been obtained, but conclusions as to the mechanism of disintegration in these cases cannot yet be drawn. Greater technical difficulties arise in the investigation of such short ranges, and attempts are being made to develop a more suitable method.

DISCUSSION on *The positive electron* (Mr. P. M. S. BLACKETT and others) :—

Mr. P. M. S. BLACKETT (12.0).

Positive electrons are produced in certain types of collision processes. Their first detection, by Anderson and by Blackett and Occhialini, was due to the study of cosmic rays by the cloud method. These photographs showed the presence of positively charged particles with a mass comparable with that of a negative electron. From the ionisation along their tracks it can be deduced that the mass and charge of the positive electron do not differ in magnitude from those of the negative electron by more than 50 per cent. The positive electrons appear to originate in some type of atomic or nuclear process brought about by the incident cosmic radiation.

Positive electrons have also been found by Chadwick, Blackett and Occhialini, by Curie and Joliot, and by Meitner and Phillip to be produced when the radiation from a beryllium target is bombarded by alpha particles. The measurements of Curie and Joliot suggest that they are produced by the hard gamma rays emitted by the source rather than by the neutrons. It has further been shown by Anderson that positive electrons are also produced when the gamma rays from Thorium C″ are absorbed by heavy elements. It is therefore probable that the production of positive electrons plays an important part in the anomalous absorption of gamma rays.

Tuesday, September 12.

Discussion on *The expanding universe* (10.0) :—

Prof. Sir A. S. Eddington, F.R.S.—*The expanding universe.*

The observational facts which led to the idea of an 'expanding universe' are, I think, pretty well known. Outside our own galaxy of stars there are millions of other galaxies which appear to us as spiral nebulæ ; and these (so far as they have been observed) are found to be running away from us. The greater the distance, the faster they move ; and approximately, at least, the speed is proportional to the distance. This progression of speed with distance has been traced up to a distance of 150 million light years, where the speed amounts to 15,000 miles a second. For the moment we stop there because observation is becoming too difficult, but no doubt in due time still more remote nebulæ with still higher speeds will be found.

If we plot this distribution of motion it is easy to see that the spiral nebulæ are running away from each other just as much as they are running away from us. It is, therefore, not a case of scattering away from one point, but a general uniform expansion or dispersal in which all mutual distances are increasing in the same proportion. We have therefore an expanding system of galaxies—or, since the system of galaxies is all the universe we know, an expanding universe. We may therefore say it is a simple, direct fact of observation that our material universe is expanding. Whether it has always been expanding and always will expand is another question.

I do not think the speakers who are to follow me will challenge this—I am judging by what I already know of their views—and it will probably be accepted as the common basis of discussion. It is therefore, perhaps, all the more incumbent on me to say that it is not universally accepted as proved ; there is scepticism in some quarters, and it must not be assumed that either I or the other speakers regard this scepticism entirely with contempt. We have generalised from data which are not so extensive and not so accurate as we could wish. It is often pointed out that what we actually observe is a red shift of the spectrum of the nebulæ ; and although a red shift of the spectrum usually means that the object is running away from us, it is possible that there might be other causes. We can only reply that if some other cause is operating in the case of the spiral nebulæ, it is some entirely unknown circumstance of which we have as yet no hint, either in theory or observation. I suppose that entirely unknown circumstances might upset all our scientific inferences, and there seems no need specially to introduce this bogy in connection with nebular velocities.

Turning to theory, it is a necessary consequence of the theory of relativity that there should exist in addition to the ordinary gravitation of bodies a repulsive force which we call 'cosmical repulsion.' This is too small to affect small-scale systems such as the solar system, and we can only expect to detect it in a system on the largest possible scale—if it is detectable at all. Cosmical repulsion is of such a nature that if it acted on a system of galaxies at rest it would make it expand uniformly—just the type of expansion or dispersal that we observe. We must not forget that the galaxies are attracting one another in the ordinary way, and that this attraction might, in certain circumstances, hold the dispersing force in check. However, if the dispersing force once gets the upper hand it will keep it ; because as it drives the galaxies further apart their mutual attraction will weaken and offer less opposition to the dispersal.

Thus observation tells us that the galaxies form an expanding system; and theory tells us that there is a force of cosmical repulsion which, if not counteracted, will produce just such an expansion. So far, so good. But there is still a doubt whether the theory has anything to do with the observation, because the relativity theory omits to tell us how large the force of cosmical repulsion will be. So far as the current theory is concerned, it might be imperceptible in the system of the galaxies. Therefore, having no idea of the size of the effect, it is rather a big jump to identify it with the first thing we come across that looks at all like it. I have tried to contribute to the settlement of this question by developing relativity theory (with the aid of wave mechanics) in a way which leads to a direct calculation of the amount of the cosmical repulsion. I have to begin at the other end of things and ask you to consider the mass of an electron.

By the mass of the electron we mean the mass in C.G.S. units—i.e. in terms of the standard kilogram. Accordingly, in any experimental determination of the mass of an electron, whatever auxiliary apparatus may be employed, there are two indispensables, viz. an electron and the lump of metal called the standard kilogram. The experimenter cannot proceed without a theory: he reads certain deflections, angles, etc.; but he would not know what to do with these, unless a theorist gave him directions how to combine them and extract the numerical quantity m out of them. What is this theory—these equations which connect the behaviour of the two indispensables, the electron and the kilogram mass? The experiment will consist of a number of links, and each link will have its corresponding theory; at the electron end we shall use microscopic, i.e. quantum theory; at the kilogram end we shall use macroscopic theory, i.e. classical mechanics, or, for greater refinement, relativity theory. But there must be one link which unites a microscopic mass with a macroscopic mass, included neither in quantum theory nor in relativity theory but with one end in each. It is this link that my investigation supplies. It will be said that this link is already known; we know how to make the step from microscopic to macroscopic theory, e.g. as in Bohr's Correspondence Principle. Quite so. We know how to do it; it only remains to do it—to find what formulæ result in this particular problem. I do not require any new hypothesis in my investigation: it is the mathematical working out of principles already accepted. The result is that microscopic and macroscopic masses are linked through the equation

$$10m^2 - 136mm_0 + m_0^2 = 0$$

where m is the mass attributed to the single particle and m_0 is the mass of the reference frame to which it is implicitly referred.

In passing it may be mentioned that this equation gives two values of m, one $1847 \cdot 6$ times the other, which is as nearly as we can tell the ratio of the mass of the proton to that of the electron. But we are more concerned with m_0, which is connected with cosmical magnitudes. I will try to show, by a short cut, how the mass of the reference frame arises. The argument will probably appear fishy—as short cuts generally are. But I have also found the same result by going the long way round. The short cut depends on the Uncertainty Principle.

If we have a particle in space of radius of curvature R and know nothing at all about its location, we may express its uncertainty of position as $\pm R$; $\pm$ is here an abbreviation for 'in an unknown direction.' The particle is 'distant' R from the centre of curvature of space in an unknown direction. By the Uncertainty Principle the corresponding uncertainty of momentum is $\pm h/2\pi R$; that is to say, it has a momentum $h/2\pi R$ in an unknown direction

arising out of the uncertainty relation. If we take a frame of reference constituted out of the mean of N such particles, the uncertainty of position of the mean is $\pm R/\sqrt{N}$ according to the usual theory of combination of vectors in random directions, and the corresponding momentum is $\sqrt{N}h/2\pi R$ in an unknown direction. The proper mass is obtained by dividing the momentum by c. Hence the frame has a mass

$$m_0 = \frac{h}{2\pi c} \frac{\sqrt{N}}{R}$$

In quantum theory (which follows the methods of statistical mechanics) we lay down what is called ' an *a priori* probability distribution ' of the electron or electrons considered, and this serves as a frame of reference. This will give an average density and average momentum at all points, and hence an energy-tensor. By Einstein's equation the energy-tensor corresponds to a curvature of space. This curvature is usually neglected in quantum mechanics ; but in the linkage between microscopic theory and macroscopic theory it is clearly of fundamental importance, since macroscopic mass corresponds to space-time curvature. Without going into details, we may conclude that it is necessary to identify the curvature due to the *a priori* probability distribution of particles in quantum theory with the curvature $\lambda g_{\mu\nu}$ which forms the standard with which the curvature due to macroscopic objects is compared. Each theory uses a standard distribution in the way that a geodesist uses a geoid ; and to unite microscopic and macroscopic theory we have to adapt them to the same geoid. The result is that N is the number of particles in the whole universe and R the ' de Sitter ' radius of space-time. The two formulæ above given determine $\sqrt{N}/R$ in terms of the mass m of an electron or proton.

Knowing $\sqrt{N}/R$, we can find the theoretical value of the limiting speed of recession of distant objects. It turns out to be 780 km. per sec. per megaparsec. The observed value (which is subject to considerable uncertainty, and may be a little less than the limiting speed owing to the gravitational attraction of the nebulæ on one another) is 550 km. per sec. per megaparsec.

Prof. E. A. Milne, M.B.E., F.R.S.

The earliest reference I have found to the expansion of the universe is Genesis i. 6, when the Authorized Version gives in a marginal note the information that in Hebrew the word ' firmament ' means also ' expansion.' We may conjecture that if allusion could be made to the expansion of the universe in so primitive a cosmology as that ascribed to Moses, then the expansion itself must be a very primitive phenomenon. This seems to be the case.

The observed motions of the extra-galactic nebulæ, considered as units, are utterly different from the Keplerian motions of the planets in the solar system, from double-star orbits, and from the motion known as star-streaming and galactic rotation. The extra-galactic nebulæ are simply separating from one another. This is a characteristic of any system of particles in free flight, or endowed with velocities sufficiently large to escape from the gravitational attraction of the remainder. Such a system, from the moment at which it is first given (save for negligibly improbable initial conditions) inevitably expands, and its constituent particles sort themselves out in velocity, the fastest being the furthest at any given epoch, followed by the next fastest, and so on. The velocity zones partially over-

lap, but the velocity segregation becomes more perfect with increasing time. Further, the relation between velocity v and distance r, measured from any particle of the system, is a simple proportionality $v \sim r/t$, where t is the time that has elapsed since the system was first given. These characteristics hold for any system of particles unconfined by any rigid boundary, free to occupy an indefinitely large volume of space. The epoch at which the system is first given is the epoch of minimum volume of the system, and affords a natural time-zero. At this instant (except for negligibly improbable distributions) both the system itself and its velocity-reverse necessarily undergo expansion.

It appears then that the motion of a gravitation-free system of particles, or of any system with sufficiently large speeds, reproduces the observed motions of the extra-galactic nebulæ in the three characteristics of expansion, velocity-zoning and a velocity-distance proportionality. The value of t, our present epoch, reckoned from the epoch of minimum volume, comes out at about 2×10^9 years ; this simply describes the position of the epoch we happen to be experiencing. On a broad view then it is suggested that the system of the nebulæ is that of a system of particles in free flight, subject to zero or negligible gravitational influences. In any case the expansion is an inevitable phenomenon, arising kinematically and not in virtue of gravitation ; repulsive forces are not required to be invoked to account for it. It is a primitive phenomenon, as foreshadowed by the author of Genesis. It is *the most natural thing in the world.*

The expansion phenomenon itself, however, is only a part of the general cosmological problem, which is that of the distribution of both matter and motion in the universe. The usual theory of relativistic cosmology assumes part of the answer to this problem outright : it assumes that the universe is homogeneous. For a world devoid of motion the notion of homogeneity is unambiguous. If the density at any point, to any one observer attached to a stationary particle of the system, is the same as at any other point, then the same will be true for any second observer attached to some other particle of the system. But if to one observer A the universe is homogeneous but changing in density with the time owing to the motion, then it cannot appear homogeneous to a second observer B attached to some other particle in relative motion with respect to A. For by saying that the universe is homogeneous to A, we mean that at a world-wide instant t for him (i.e. at instants simultaneous in his reckoning) the density at P equals the density at Q : $\rho(P, t) = \rho(Q, t)$. But these will not be in general simultaneous instants for B ; consequently, if the universe is also homogeneous to B, he will consider A to be measuring the density at different times, when accordingly the density $\rho(P)$ is not equal to the density $\rho(Q)$. This is a contradiction. Einstein, in destroying the notion of absolute simultaneity, destroyed also the notion of absolute homogeneity for a system whose density is not constant in time. The usual theory of relativity cosmology evades this difficulty by constructing a map of the world in which the ' surfaces of constant density ' are labelled ' surfaces of constant cosmic time τ ' ; τ is not the time of experience, and surfaces ' τ = constant ' are not ' spatial ' sections of experience. The homogeneity of the section ' τ = constant ' is a fictitious homogeneity, obtained by examining each element of the universe at the stage at which its density, measured locally, takes a given value. No inference can be made as to the homogeneity or otherwise of an actual spatial section of experience until cosmic time τ is linked with experienced time t, as has been done recently by Dr. McCrea and others. The resulting maps of the world are ' expanding maps.' They are maps of a very particular kind, since on the general theory of relativity, given the distribution of

matter in motion, the curvature of the map to be used is definite. The geometry of any map is, however, a matter of the arbitrary choice of axioms. But just as it is legitimate to use curved maps and expanding maps, so, if we free ourselves from the restrictions in map-drawing imposed by the general theory of relativity, we can use flat maps and stationary maps. 'Space' in the abstract is a non-entity, like the aether, and hence to talk of 'curved space' or 'expanding space' is to label as phenomena of nature what are really attributes of a man-made map. The picture of the expansion phenomenon obtained by the consideration of a swarm of particles is a case of the use of an ordinary flat map.

Instead of making any direct assumption as to the homogeneity or otherwise of the smoothed-out universe, we may return to the kinematic system previously considered and simply ask what must be its velocity distribution if it is to possess no preferential velocity-frame—that is, if the velocity distribution is to be the same from whatever particle the system is viewed. We must, of course, employ some principle to correlate the observations of different particle-observers. A sufficient principle is that, for any two particle-observers in uniform relative motion, each observer is completely equivalent to the other. When each particle-observer possesses a temporal experience, it is then possible to infer[1] the Lorentz formulæ of 'special' relativity, which are thus available for correlating the observers' descriptions of events.

It is then readily found that the velocity distribution must be of the form

$$\frac{B\,du\,dv\,dw}{c^3\,(1-\Sigma u^2/c^2)^2}$$

where B is a constant, u, v, w being the components of velocity. It then follows, by making the substitutions

$$u \sim \frac{x}{t},\; v \sim \frac{y}{t},\; w \sim \frac{z}{t}$$

that the spatial distribution tends to the asymptotic form

$$\frac{Bt\,dx\,dy\,dz}{c^3\,(t^2-\Sigma x^2/c^2)^2}$$

which gives the particle-density. This can now be considered as an ideal world-model. It represents a hydrodynamical system of flow satisfying the equation of continuity.

This system has very remarkable properties. Each particle-observer is equally the centre of the system. To any such particle-observer, at his epoch t the system appears to occupy the interior of an expanding sphere of radius ct, the particles being distributed inside this sphere homogeneously near the observer but with increasing density towards the boundary. Near the boundary itself the particles are nearly invisible, owing to recession with the speed of light. The density tends to infinity at the boundary. This singularity, at time t in the experience of the central observer, is the counterpart of the singularity in his past history at $t = 0$, the natural time-zero. The system includes an infinite number of particles, but the total brightness is finite.

The system not only possesses no centre, it possesses no mean velocity. Thus it defines no absolute frame of rest—every particle-observer may equally consider himself as at rest relative to the system. Further, it

[1] It is even possible to define what is meant by 'uniform relative motion' in terms only of the temporal experiences of the observers.

possesses no unique radius or unique age at any given event. If in the experience of a central observer O, who assigns at a certain epoch of his experience the radius ct to the system, an event occurs on another particle P, moving with radial velocity V at the same time t, then at this event P assigns to the system the radius $ct(1 - V^2/c^2)^{\frac{1}{2}}$, and 'age' $t(1 - V^2/c^2)^{\frac{1}{2}}$. Thus at a given event the radius or age of the system depend on the observer observing this event. Particle-observers close to the boundary (in the experience of a given observer) are to themselves close to the time-zero. In the experience of a given observer, the system always (i.e. for any t) contains particles arbitrarily close, in their own experience, to the singularity called by Friedmann 'creation.' An observer reckoning himself as central assigns a greater age to the system than any of the other observers in his world-wide present, and so reckons himself as the 'oldest inhabitant' of the system. Every other observer does the same. Each observer has a definite temporal experience (say, measured by his local density), and in observing other particles witnesses experiences similar to those of his own past; but he can never witness experiences similar to those of his own future.

Though each particle-observer experiences an evolutionary history, there is no meaning to be attached to saying that the system *as a whole* is evolving; it always contains experiences arbitrarily early in time, reckoned from the time-zero. This is markedly different from the conclusion of de Sitter in a recent paper (*M.N.* June 1933) that 'the present structure of the universe is only an episode of a very ephemeral character.' It appears to me that, although of course de Sitter is well aware that cosmic time is not the time of experience, save locally, he has here inadvertently interpreted a section 'τ = constant' as a world-wide section in an observer's *present*.

The above properties refer to the *world-map* made by a given observer, from his observation of *world-pictures*. The world-picture he observes at epoch t is readily specified. If r_1 is the distance of a particle or nebula at the time when it emitted light which arrives at the observer at time t (a given epoch), then its velocity V is given by

$$V = r_1/(t - r_1/c)$$

and the density 'distribution' in the world-picture at time t is given by

$$\frac{4\pi B\, r_1^2 dr_1}{c^3\, t(t - 2r_1/c)^2}$$

The *world-picture* necessarily has a radius $\frac{1}{2}\, ct$. The interest of the density-formula for the world-picture is that it gives a first-order increase of density with increasing distance. This is a necessary consequence of the expansion, for in passing from the world-map to the world-picture we must compress the outer portions proportionally more than the inner, as the outer portions have expanded more than the inner during the larger time of travel of the light. This prediction is not peculiar to my model—it holds for any locally homogeneous world-map in which the motion obeys a velocity-distance proportionality. Observation of position-distribution of nebulæ made at a given instant—i.e. counts of nebulæ on photographs—should already disclose this effect; but the inference of distance from apparent brightness must also allow for the reduction in luminosity due to the recession of the sources.

Each particle of my ideal model is in uniform motion with respect to any other. The question arises whether this state of motion will maintain itself if the particles are supposed to act on one another according to any assigned law of gravitation compatible with relativity. It can easily be shown that the resultant gravitational field of this system of particles in motion is zero,

whatever the density. For consider a system of *frames of reference* distributed according to the above laws, and place a particle in each instantaneously at rest in its own frame. The given particle O, being central with respect to the system, in its own frame, has zero acceleration in its own frame. Let f be the radial acceleration of a particle P, measured in the frame of O. Transform to the frame associated with P. Let f' be the resulting acceleration of P, in its associated frame. Then in this frame P is central, and so f' is zero. Hence, by the Lorentz formulæ for accelerations, f is zero. The system is thus self-screened from gravitation. *It goes on of itself.* It is a sort of Faraday chamber—it resembles the interior of an electrostatic conductor. The universe as here pictured realises H. G. Wells's dream of a perfect gravitational shield.

This conclusion has been recently criticised by Drs. McCrea and Kermack. These authors claim that I have left out gravitation. The above proof seems to me to dispose of their objections. The accelerations they calculate refer to an expanding-map universe of non-zero density, but they have not re-mapped their system in the flat space I am using for comparison with my model. The freedom of the *ideal* system from gravitation shows that the *actual* system will have only a small residual gravitational field, and so justifies the original comparison with a swarm of particles in free flight.

Much further information may be obtained by a less complete degree of smoothing out than is implied by the reduction of the world to a hydrodynamical system. If we construct a statistical spatio-velocity distribution in which the members of each pair of particles in uniform motion have indistinguishable world-views, we find a distribution

$$\frac{\psi(Z^2/XY)\, dx\, dy\, dz\, du\, dv\, dw}{c^6\, X^{\frac{3}{2}}\, Y^{\frac{5}{2}}}$$

where

$$X = t^2 - \frac{\Sigma x^2}{c^2}, Y = 1 - \frac{\Sigma u^2}{c^2}, Z = t - \frac{\Sigma ux}{c^2}$$

and ψ is undetermined. Imposition of the principle of conservation of particle-number—the condition that the object counted have a permanent existence—determines the components of acceleration f, g, h as

$$\begin{aligned} f &= -(x - ut)\frac{Y}{X}\left[1 - \frac{C}{(\xi - 1)^{\frac{3}{2}}\psi(\xi)}\right] \\ g &= -(y - vt)\frac{Y}{X}\left[1 - \frac{C}{(\xi - 1)^{\frac{3}{2}}\psi(\xi)}\right] \qquad (\xi = Z^2/XY) \\ h &= -(z - wt)\frac{Y}{X}\left[1 - \frac{C}{(\xi - 1)^{\frac{3}{2}}\psi(\xi)}\right] \end{aligned}$$

Thus the accelerations are definite, apart from an undetermined constant C, as soon as ψ is specified, and thus there is a connection between the distribution of matter and motion and the acceleration. This is what we mean by a law of gravitation. We notice that the accelerations vanish for the particles for which $u = x/t$, $v = y/t$, $w = z/t$. This confirms our earlier conclusion as to the freedom of such a sub-system of particles from gravitation. The mean particle-density n of this statistical distribution can be shown to be (as judged by the observer at (0, 0, 0) at his epoch t)

$$n = \frac{4\pi t}{c^3(t^2 - \Sigma x^2/c^2)^2}\int_{(1 - \Sigma x^2/c^2t^2)^{-\frac{1}{2}}}^{\infty} \frac{2s^2 - 1}{(s^2 - 1)^{\frac{1}{2}}}\, ds \int_{s}^{\infty} \psi(\eta^2)d\eta \quad .$$

which can be reduced to

$$n = \frac{2\pi t}{c^3(t^2 - \Sigma x^2/c^2)^2} \int_{\frac{r^2}{c^2t^2 - r^2}}^{\infty} \left[\zeta^{\frac{1}{2}} - \frac{ctr}{c^2t^2 - r^2} \cdot \frac{1}{(1 + \zeta)^{\frac{1}{2}}}\right] \psi(1 + \zeta) d\zeta$$

It thus reproduces in broad outline, though not exactly, the hydrodynamical density-distribution. Again, the mean radial velocity at (x, y, z) at time t, say $\bar{v}_r$, can be shown to be

$$\bar{v}_r = \frac{r}{t} + c\left(1 - \frac{r^2}{c^2t^2}\right)^{\frac{1}{2}} \frac{\displaystyle\int_{(1 - r^2/c^2t^2)^{-\frac{1}{2}}}^{\infty} ds \int_s^{\infty} \psi(\eta^2) d\eta}{\displaystyle\int_{(1 - r^2/c^2t^2)^{-\frac{1}{2}}}^{\infty} \frac{2s^2 - 1}{(s^2 - 1)^{\frac{1}{2}}} ds \int_s^{\infty} \psi(\eta^2) d\eta}$$

where $r = (x^2 + y^2 + z^2)^{\frac{1}{2}}$. The second term is always small, and so the statistical system reproduces in broad outline the motion of the hydrodynamical system. But near $r = 0$, the second term is dominant to the first (though itself tending to 0 as $r \to 0$) and so gives a local ‘ K-effect ’ when the cosmical recession is negligible.

We can, however, go much further. We can choose the distribution ψ in such a way that for a particle of zero velocity near the observer, the radial acceleration $(f_{r,0})$ satisfies the condition that

$$-f_{r,0} \Big/ \frac{1}{r^2} \int_0^r 4\pi n r^2 dr$$

has a finite limit as $r \to 0$. This limit will be described by a Newtonian observer as Gm, where m is the mass he assigns to a particle of the system and G is the Newtonian ‘ constant ’ of gravitation. It is clear that $\psi(\xi)$ must possess a singularity at $\xi = 1$, and the above relation determines the singularity as of the form

$$\psi(1 + \zeta) \sim \frac{A}{\zeta^{\frac{3}{2}}} \left(\log \frac{1}{\zeta}\right)^{-\frac{1}{2}} \qquad (\zeta \sim 0)$$

It is then found that n possesses a very mild singularity at $r \sim 0$,

$$n \sim \frac{4\pi A}{c^3 t^3} \left(\log \frac{c^2t^2}{r^2}\right)^{+\frac{1}{2}}$$

so that the number enclosed in a sphere of radius r tends to 0 as $r \to 0$. The singularity is so mild that the mean density inside the sphere of radius r is practically equal to the density at r itself. The singularity is no longer evident at quite small distances from $r = 0$, and here the mean mass-density $\bar{\rho}$ comes out to be

$$\bar{\rho} \sim \frac{1}{\frac{4}{3}\pi G t^2}$$

This must agree with the central mass-density in the hydrodynamical model, namely, $m_1 B/c^3 t^3$, where m_1 is the mass of a nebula ; whence we find

$$B = \frac{c^3 t}{\frac{4}{3}\pi m_1 G}$$

and from this

$$\frac{C}{A^2} = -\frac{16\pi^2}{3}\frac{mG}{c^3t}$$

A physical meaning can be given to these formulæ. Let the sphere of radius ct in the hydrodynamical model be filled homogeneously with matter of density equal to the central density (density near the observer). The total mass of the ' extrapolated homogeneous universe ' is then

$$\tfrac{4}{3}\pi(ct)^3\frac{m_1B}{c^3t^3} = \tfrac{4}{3}\pi m_1B = \frac{c^3t}{G}$$

Accordingly c^3t/G is a world-constant ($\tfrac{4}{3}\pi m_1 B$). Its value is about

$$2{\cdot}4 \times 10^{55} \text{ grams},$$

the mass assigned by the theory of Lemaître to his finite universe. This is the world-constant on which Eddington bases his theory of the proton. It is the only independent *constant* occurring in the present theory, and it is determined from observation. Since B is a constant, we must have $G \propto t$. The Newtonian ' constant ' of gravitation should be proportional to our present epoch, measured from the natural zero of time.

The mean density $\bar{\rho}$ of the smoothed-out universe near the observer, at our present epoch, should be $(\tfrac{4}{3}\pi G t^2)^{-1}$. Taking, for t, 2×10^9 years, this gives $\bar{\rho} = 10^{-27}$ gram cm.$^{-3}$. If we spread the estimated population of our galaxy, 10^{11} suns, over a cube of side equal to the distance of the Andromeda nebula (approximately our nearest galactic neighbour), we obtain just under $0{\cdot}3 \times 10^{-27}$ gram cm.$^{-3}$. The agreement is as good as could be expected. This formula for the central density is numerically the same as the formula for the *mean* density of the homogeneous universes of other theories.

The analysis of the statistical world-system then, when ψ is properly chosen, yields the remarkable property that the observer sees a mild singularity in density near himself, but nowhere else ; it predicts a local density roughly equal to that observed, and it suggests that the finite mass of the universe in the theory of Lemaître is an extrapolation due to the identification of ' cosmic time ' with experienced time. (The two only coincide near the observer.)[2] In that theory, of course, G is treated as a constant.

The cosmological principle employed in the above—the equivalence of uniformly moving observers in their world-wide experiences—implies the Lorentz formulæ of ' special ' relativity and a very general law of gravitation. One particular distribution, out of the permissible ones, agrees for resting particles near the observer with Newtonian gravitation ; save that now $G \propto t$. The definition of world-systems in the usual relativistic cosmologies is by means of a ' local homogeneity ' postulate, which then requires to be supplemented by the use of Einstein's theory of gravitation. The cosmological principle I employ is thus very powerful. It has the advantage of making possible the use of a flat non-expanding map for the description of the world, and the further advantage of beginning with actual temporal experience ; the other cosmologies require a translation of their cosmic time into the time of experience, before yielding descriptions of phenomena as observed. The general cosmological principle removes the necessity for attributing any special properties to the phase of world-history we happen to be witnessing, and it correctly predicts the leading features of this world-history. Its bearing on world-evolution and its avoidance of any ultimate ' heat-death ' for the universe cannot be treated here. The cosmological

[2] As shown by McCrea and Kermack (*M.N.*, June 1933).

principle here employed differs from the homogeneity principle of relativistic cosmology in that it compares the world-wide experiences of observers with one another, whereas the homogeneity principle compares merely their local experiences. But the theory here outlined agrees in many quantitative respects with the general relativity theories. It avoids, however, such predictions as the possibility of closed light-circuits, or the prediction of the ultimate dissolution of the universe into causally disconnected systems. All roads lead to heaven, or, at worst, those which lead elsewhere are paved with good intentions.

Dr. G. C. McVittie.—*Condensations of matter in an expanding universe.*

In the expanding universe theory as originally developed by Lemaître it was assumed that a fair approximation to the actual universe could be obtained by treating all the matter in the universe as if it were evenly spread out in space so as to form a cosmic cloud. Like a gas or fluid, this cosmic cloud is characterised by possessing a definite density and pressure at each point. But actually the matter in the universe is not evenly spread out in space : it occurs in the form of discrete masses, such as the spiral nebulæ or the stars, separated by regions of comparatively empty space. The question therefore arises : Can the theory of the expanding universe be adjusted so as to take account of the discontinuous distribution of matter in the universe ? The answer to this question is found to be closely bound up with a number of problems left unsolved by the theory of Lemaître.

We have, then, to substitute for Lemaître's cosmic cloud a set of discrete massive 'particles,' as I shall call them, or condensations of the cosmic cloud. Put mathematically, we have to find, by solving the equations of general relativity, the metric of a universe occupied by an arbitrary number of discrete particles. At the very outset it must be admitted that no one has yet succeeded in doing this. Even if we assume that there are only two particles in the universe, the problem proves intractable. So we try to dodge the difficulty in the following way : we concentrate our attention on one particle and smooth out all the others so that their material forms a cosmic cloud of the type imagined by Lemaître. Thus our solitary particle, instead of being surrounded by empty space in which other particles occur here and there, is surrounded by a cosmic cloud which fills practically the whole universe. It turns out that the equations of general relativity are soluble for such a case. The solution is not, however, unique : various types of single particles surrounded by cosmic clouds are possible. One particle, for instance, is of constant mass ; another grows at the expense of the cosmic cloud. Moreover, the presence of the particle causes changes in the density, pressure and state of flow of the cosmic cloud in its immediate neighbourhood. Further away, however, these disturbances become quite negligible, and the universe approximates closely to the completely smoothed-out universe of Lemaître's theory.

Having obtained these solutions, we can now turn to the problems already mentioned which were left untouched by Lemaître's theory. The chief of these is, perhaps, the question of the disturbance of the equilibrium of the Einstein universe. It is probable that our own universe started to expand from a state of equilibrium in which the cosmic cloud had constant density everywhere and approximately zero pressure. Space was also spherical and closed. Such a state of affairs had been known long before Lemaître's theory was thought of, under the name of the Einstein universe.

Its equilibrium, it is easy to show, is unstable : an appropriate impulse will set it off either expanding or contracting. Now Lemaître's theory gave no indication as to why it should begin doing the one rather than the other. It was the inquiry whether the condensation of the cosmic cloud in the Einstein universe into particles would start it expanding, that first gave rise to the theory of condensations.

Unfortunately, the effects produced by the formation of particles on the equilibrium of the Einstein universe turned out to be much more numerous and complex than appeared at first sight. The reason is that the disturbance of the equilibrium is a second-order effect : to a first approximation the formation of the particles has no effect whatever on the equilibrium. This so complicates the problem mathematically that no really satisfactory method of solution has yet been evolved. Instead attempts have been made to decide on more or less *a priori* grounds which one of the many perturbations produced by the particle is the predominating one from the point of view of upsetting the equilibrium. Lemaître, for example, has tried to show that the presence of the particle never has any direct effect on the equilibrium at all, on the ground that the neutral zone surrounding the particle must always remain in equilibrium. This neutral zone is the region where the gravitational effect of the particle is balanced by that of the cosmic cloud. He postulates instead that expansion is due to a diminution in the pressure of the cosmic cloud at this neutral zone. Unfortunately, it seems doubtful whether particles do actually possess these neutral zones ; and, moreover, it cannot be proved that there must be a *diminution* in the pressure at the neutral zone, supposing the latter to exist.

Another investigator, N. R. Sen, has put forward a theory that expansion is caused by the very effect Lemaître disbelieves in, viz. the mere presence of particles. Sen neglects all possible counterbalancing effects such as changes in pressure in the cosmic cloud, and shows that, under *these* circumstances, the formation of a particle in the Einstein universe is impossible unless expansion sets in. His theory certainly seems more convincing than Lemaître's, but in both cases you will see that the attempts to solve this problem suffer from over-simplification. The most we can say to-day is that it is probable that the bubble of our universe began to burst the moment those particles we call spiral nebulæ started to condense out of the primeval cosmic cloud.

I now pass to another question on which the theory of condensations sheds a more certain light. It is the much-debated one of ' cosmic ' time. The introduction of ' cosmic ' time into Lemaître's universe is directly attributable to the Einstein assumption which it satisfies : ' All points in the universe are equivalent.' This means, amongst other things, that all observers in the universe can differ from one another only in position. It then becomes possible to define a sort of time common to all of them, which has been called ' cosmic ' time, since it allows of the reintroduction of the idea of simultaneity of events. Opponents of Lemaître's theory of the expanding universe, notably E. A. Milne, have spoken as if this ' cosmic ' time were a consequence, or a necessary ingredient, of the theory. The truth is that ' cosmic ' time is an *a priori* simplification introduced into the theory by investigators anxious to make the mathematics easier ! The position becomes clearer if we allow the universe to contain a particle of the kind I have tried to describe. Consider an observer in the neighbourhood of this particle. His proximity to it marks him out as different from all other observers in the universe ; he also has a time peculiar to himself. Now it is easy to show that Lemaître's theory holds for this observer to a high degree of approximation everywhere except near the particle, with the

reservation, however, that it is not 'cosmic' time that enters into the formulæ, but the peculiar time of this observer. In other words, the so-called 'cosmic' time of an event is nothing more than the time an observer chooses to assign to it. It happens that in Lemaître's simplified theory the observers are all so alike that their 'times' can be co-ordinated so as to give the impression of a single 'cosmic' or 'absolute' time in the universe.

In conclusion, reference should be made to a question which may have occurred to most of you. If our universe is flying to pieces at the present astounding rate, how is it that periodic systems in the universe such as our Sun and his planets seem so excessively stable and permanent? The answer is supplied by the theory of condensations, which shows that an observer using the methods of measurements terrestrial astronomers employ, necessarily concludes that planetary systems are fixed and unchanging in size, whilst the system of the nebulæ expands. Conversely, if we imagine a cosmical being who looked upon the system of the nebulæ as fixed and unchanging, this being would see the Sun and his planets shrinking away to nothing. Indeed, the nature of our minds is such that we instinctively endow our immediate surroundings with an element of permanency, and relegate to the distant nebulæ the evidences of the instability of the world in which we live.

Dr. W. H. McCrea.—*The relation of Milne's theory to general relativity.*

I wish to say something about the relation of Prof. Milne's theory of world structure to the general relativity theory of the expanding universe.

There is a temptation to start with a moralising homily on the history of the subject. General relativity, through the work of Prof. de Sitter, actually predicted the systematic recession of distant nebulæ. Data derived subsequently by Hubble and others gradually accumulated to provide observational support for this apparent recession. Result: one up for general relativity! The next development was that Friedmann, Lemaître and others investigated non-static universes and arrived at the concept of the expanding universe—still using general relativity theory. The result was to make a systematic recession, or at any rate a systematic motion, of distant nebulæ seem inevitable. At the same time an explanation was given of the particular *form* of Hubble's empirical law for the observed variation of velocity of recession with distance. I should say, however, that the inevitableness of the phenomenon was apparent only to the initiated. For it was all very sophisticated and bound up with the difficult ideas of the curvature of space-time, and the mysterious cosmical constant λ.

In passing one might comment on the prevalent fashion of giving λ a name. Sir Arthur Eddington himself calls it 'Gulliver.' But I fancy he ought to call it 'Mrs. Harris.' For this friend of Sir Arthur's gets the credit for marvellous doings—as, in fact, he has just been telling us. Nevertheless, does she really exist? Einstein and de Sitter have been irreverent enough to suggest that she might be a zero quantity!

To pursue our history, however, we next come to an unexpected move. Prof. Milne suggested an explanation of the scattering of the galaxies, which he has just explained to us, which makes the whole thing seem intuitive in an absurdly simple way. As Milne himself has remarked, had this explanation occurred to anyone before the advent of general relativity, it would probably have been immediately hailed as the obvious one. At this point someone is doubtless heard to murmur: 'What a pity Prof. Milne did not arrive on the scene fifteen years sooner and save us all this trouble of trying

to fathom the general relativity theory!' It is, however, my purpose to-day to show that it is fortunate that things turned out as they did. For I believe that general relativity provides the best mathematical method for dealing with Milne's phenomenon, and I am thankful that he had patience to wait till this method had been discovered before giving us his own theory, which otherwise might have been taken to be the last word. In short, general relativity was all the time studying the simple phenomenon contemplated by Milne, but somehow never realised the fact! Only general relativity goes somewhat further, and takes account of the influence of gravitation, and also of the influence of the cosmical constant—that is, if Mrs. Harris really does interfere.

The results I am about to summarise were arrived at in collaboration with Dr. Kermack of Edinburgh.[1] We discovered afterwards that Prof. H. P. Robertson [2] of Princeton had simultaneously arrived at identical conclusions.

Milne has stated his postulates. He wants a universe in which every observer, or every one of a particular class of observers, sees the same sequence of world-pictures. To fix the ideas we take the simplest solution of his problem, which is provided by his 'hydrodynamic' solution. This represents a set of particles all setting out from a single point with uniform velocities relative to each other. If the velocities are distributed from zero up to the velocity of light, in the particular manner calculated by Milne, then each observer will see himself for all time as the centre of the whole bunch. Any observer at any instant will describe the universe by associating with each point the velocity and density of particles found by Milne.

Now, in arriving at these results, Milne chooses to *map* his events in a four-dimensional Minkowski space. He is quite entitled to do this. For his space-time is introduced from a different standpoint from space-time in general relativity. He chooses his space-time first, and then seeks the law of gravitation for the actual universe which will reproduce the observed state of affairs. General relativity, on the other hand, puts the law of gravitation first, and then seeks the form of space-time for the actual universe, again so that the observed state of affairs is reproduced. These two distinct methods of approach must always be possible.

Now there is one case in which the space-time of general relativity reduces to the space of Milne's map. That is when we neglect the effect of gravity. In general relativity, however, the result of neglecting gravity is equivalent to flattening out curved space-time. But the general relativity theory of the expanding universe admits a whole class of curved spaces. What we can show then is that, *if we choose the right one of these expanding universes, with* $\lambda = 0$, and flatten it out, i.e. *neglect the gravitational interaction of the particles, then we get exactly Milne's universe described above.* We get identically the same velocity and identically the same density associated with a given point at a given time. So this particular general relativity solution enjoys all the virtues of Milne's solution, in particular its simplicity and its explanation of why the universe appears to be expanding and not contracting.

This is very important, for, as I have already mentioned, *it means that the mysterious expansion of the universe is nothing more or less than the simple kinematical scattering of Milne's theory*, allowing, of course, in the general case for the influence on the scattering of the gravitational interaction of the particles. General relativity has, so to speak, invented a way of doing sums, but had to wait for Prof. Milne to come along and tell us what the sums

[1] W. O. Kermack and W. H. McCrea, *M.N., R.A.S.*, **93**, 519–529 (1933).
[2] H. P. Robertson, *Zeit. für Astrophysik*, **6**, in press (1933).

were all about. But I think I still prefer the general relativity way of doing the sums.

Two qualifications must be appended to this result. First, it holds, as stated, only if $\lambda = 0$. If $\lambda \neq 0$, we get a scattering of galaxies dependent on the value of λ, and if we take the simplest case and neglect the gravitational interaction of the matter, we get de Sitter's universe. If further we make $\lambda \rightarrow 0$, we find that the velocity of scattering $\rightarrow 0$ also. So this kind of scattering is physically different from Milne's.

Second, I suspect Prof. Milne might object to my saying that his calculation neglects gravitation. For he would contend, if I understand him aright, that large-scale gravitation is just such as to reproduce this particular kind of scattering found by him, and no other. I would answer that I believe it possible to show that his theory certainly does not take account of the *detailed* interaction of pairs of particles. As regards the large-scale effect it is, as a matter of fact, contrary to the strict spirit of general relativity to distinguish kinematical and gravitational effects, for the method of general relativity is to turn all dynamics into kinematics. Consequently, his objection would be quite consonant with a proper relativistic outlook. Nevertheless, I think that the language we have been employing does help in the physical understanding of the phenomena.

This latter point seems to me largely one of epistemology. The point of real importance is, what happens to Milne's theory when the detailed gravitational interaction of the particles is allowed for. Actually general relativity provides what is, within its own field of postulates, a complete solution of the problem which Milne sets out to solve, taking full account of gravitation. For, in starting with the invariance of the element of interval, general relativity ensures the constancy of the velocity of light. *Thus the first of Milne's requirements is satisfied.*

Then, further, the expanding universes of general relativity are based on the requirements of *isotropy and homogeneity*. These ensure that an observer at rest in the spatial co-ordinates sees the world as isotropic, i.e. as spherically symmetrical about himself, and that all such observers have the same view of the world at the same cosmic instant.[3] If, then, these observers be taken as Milne's fundamental class, *they satisfy precisely the requirement he makes that each should have exactly the same sequence of world views.* All the general relativity solutions satisfying these requirements are known.[4]

It is important to recall, as I was recently reminded by a conversation with M. l'Abbé Lemaître and Dr. McVittie, that these solutions are independent, in the first place, of Einstein's law of gravitation, and are derived only from the invariance of the element of interval. The law of gravitation merely gives the value of the density-momentum tensor associated with each solution. A different law of gravitation might lead to a different value of the tensor associated with any particular universe, but it could not alter the whole class of universes satisfying the fundamental requirements.

If, then, Prof. Milne ultimately arrives at conclusions different from those of general relativity, it must be either by denying the invariance of the element of interval, or else by something equivalent to using the same

[3] Milne in his original paper, *Zeit. für Astrophysik*, **6** (1933), 1–90, criticised the concept of cosmic time, but it is pointed out by Kermack and McCrea, and by Robertson (*l.c.*), that cosmic time is implicit in his own theory. There it appears as the proper time of any one of his fundamental particles since its passage through the space-time origin.

[4] H. P. Robertson, *Proc. Nat. Acad.*

space-times as general relativity, but with a law of gravitation different from Einstein's. Otherwise the two theories will differ only in method. I believe, however, that all Prof. Milne's results so far derived are included amongst those of general relativity.

M. l'Abbé LEMAÎTRE.—*The cosmical significance of the clusters of nebulæ.*

The theory of the expanding universe seems to indicate that the universe is not older than a few thousand million years, i.e. not much older than the earth. On the other hand, the generally accepted theory of evolution of the stars with transformation of matter into radiation needs a period one thousand times greater. The conflict between these two theories could be solved if the mechanics of the expanding universe provided some means of substituting for the slow evolution of the stars a rapid evolution which would explain the formation of stars, nebulæ and clusters of nebulæ in a period of a few thousand million years.

Progress of the theory of the behaviour of local condensations in the expanding universe show, at least in the case of spherical symmetry, that each concentric shell of matter would obey the same law as a universe. But they need not all follow the law of the same universe. The universe at large, starting with a very small radius, would expand with a diminishing velocity, slow down to pass over the equilibrium radius, and then expand again for ever with an accelerated velocity. On the contrary, interior regions of a somewhat greater density might fail to attain equilibrium and contract, collapsing towards their centre, while the universe at large continues to expand. This is a new typical case of instability, very small differences in the initial density being followed in the long run by extremely great modification of the motion.

This property of the universe seems to be able to explain the rapid formation of nebulæ. But when we try to follow up this idea in more detail, we meet a very essential difficulty. For a condensation of a thousand million suns, as seems required to build up a normal nebula, the equilibrium radius would be about 80,000 light-years, although the radius of a typical elliptical nebula is not much greater than one thousand light-years. Now, although the condensation must first collapse, it will evidently rebound and cannot adjust itself to a permanent radius of one thousand light-years unless some vigorous stopping process takes place in the course of the contraction. The energy which must be taken off is really enormous, and at first sight it seems difficult to understand what mechanism would account for it. Actual computation shows that the loss of energy must be equal to the total heat content of the stars contained in the nebula. This gives the solution of the puzzle. The stopping process, which prevents the nebulæ from rebounding too far, is the formation of the stars. Before the contraction the matter was formed of gas, dust or meteorites. When the whole mass collapses towards its centre, powerful encounters take place ; the diffuse matter agglutinates suddenly into stars and the energy turned into heat by this process explains together how the new-born stars have the necessary heat to start on the sub-atomic processes which provide their continuous output of light, and why the nebulæ can adjust themselves to their present radius.

Stars and nebulæ are born together in an astronomical instant. Sudden evolution of the universe takes the place of slow evolution of the stars, with the same net result, even with equipartition of energy among the stars. The shape of the nebula depends on its initial moment of momentum, elliptical nebulæ or spiral nebulæ being born together. Here evolution

theory must give way to a statistical theory in order to compute the probability of the momentum responsible for the rotation of the nebula, and therefore of its more or less elongated shape. The total mass of the nebula is also a matter of chance. Some mass might be more probable, and therefore more frequent, than another, but nebulæ of any mass might exist, and it is no longer astonishing that we are living in a fairly large nebula.

We have used so far in these considerations the two possible types of motions which must most probably occur—the ever-expanding type of motion for the universe at large, the collapsing type for the nebula itself. Between these two types of motion there is an intermediate type, in which the motion tends to the equilibrium radius without further contraction or expansion. Although this event must be comparatively less probable it must some time occur, and we have to investigate what would happen in this case. The region under investigation would finally form a part of an Einstein universe ; it would be in equilibrium, but in unstable equilibrium. As the time-scale is short and the time of disintegration is rather long, at least for such a region of large size, we might expect it to survive. We may hope that the equilibrium would remain in the mean, but not for every small part of the region, so that local condensations must occur and form ordinary nebulæ by the mechanism we have just described, although the assembly of these nebulæ would neither contract nor expand. The result will be a cluster of nebulæ.

It is possible to test this hypothesis on the origin of the clusters of nebulæ. If it is true, all clusters must have the same density, and this density must be adjusted to the cosmical constant, as in an Einstein universe. The value of the theoretical density of a cluster can therefore be computed from Hubble's ratio of the distance to the spectroscopic velocity of the nebulæ. The data are not yet very numerous, but computation for eight clusters, according to Hubble's data, gives concordant results in good agreement with previous estimates of the mass of a nebula computed from the spectroscopic rotation or the absolute luminosity. If this hypothesis can be definitely tested it would practically determine the value of the density of matter in the universe. The result is really not new ; it simply confirms Hubble's estimates, but although Hubble's determination was thought to be subject to an uncertainty of perhaps a factor of one hundred, it would practically turn out to be exact.

Prof. W. de Sitter.—*A critical discussion of certain solutions.*

Mr. C. H. H. Franklin.—*Demonstration of the orbits of a spherically free pendulum* (12.30).

A pendulum which is free to swing over a segment of a sphere has possible paths which vary from a rotation resembling an engine governor ball to the swing of a simple pendulum in a plane ; which plane appears to rotate very slowly, but really indicates the rotation of the earth beneath it (the Foucault pendulum effect).

The intermediate orbits between the circular and the linear paths are ellipses, which latter precess at a rate dependent on the maximum and minimum angles of the pendulum and corresponding ratio of major and minor elliptical axes. This precession of the ellipse produces a pattern which corresponds to that produced by two opposed rotations having a ratio near unity (such as 100 : 101, with appropriate amplitude) ; which may be drawn by harmonograph, etc. Virtually, the pendulum behaves as if it had two frequencies ; which is in agreement with the facts that the effective length of a pendulum swinging in a circle is $\cos \alpha L$, where α is the angle of the swing maintained and L is the length of the pendulum, and in tracing a single ellipse a maximum and minimum angle and corresponding minimum and maximum effective length are reached twice.

It will be seen that the greater the angle reached, the greater the variation of effective length of the pendulum, and it is found that the rate of precession increases rapidly as the angle increases.

Also, if the ratio of major and minor axes of the ellipse is high (which, in the limit, becoming ∞, means the pendulum swinging in a plane), the rate of precession is small, in the limiting case becoming 0.

And as the ratio of the major and minor axes approaches 1, the rate of precession becomes a maximum for the angles involved.

When the pendulum is capable of swinging over a hemisphere, and is oriented to maximum and minimum angles of 180° and 90° (which is a 2 : 1 ellipse), the vertical projection of the orbit becomes a 5-loop figure, corresponding to the 3 : 2 figure with opposed rotations as produced by the twin-elliptic pendulum, etc., with appropriate amplitudes.

If the pendulum is taken above the equator of its sphere of rotation, a further reduction in the number of possible loops in the orbit appears to occur, but this is deceptive, because there is now a loop above and a loop below the equator, which correspond. Also the figuring can now be dependent on velocity, the angle of initial swing not necessarily deciding the pattern, as in small spherical angle orbits.

If the speed of projection of the pendulum is high, the orbit tends to become a great circle on its sphere, which orbit precesses in the same direction as would be the case with a gyroscope.

It follows that if the orbit is nearly in the horizontal plane, precession occurs rapidly for any given mean velocity of pendulum ; and as approaching the vertical plane precession becomes relatively slow, it should, in the limit, become zero again when the pendulum completely rotates in a vertical plane.

The rate of precession for any given inclination of great circle orbit now depends on the velocity of the pendulum bob, in the same way that the rate of precession of an unbalanced gyroscope at a given slope depends on the velocity of rotation.

Afternoon.

Visit to University College, Nottingham.

Wednesday, September 13.

Prof. DAYTON C. MILLER.—*The ether-drift experiment, and the absolute motion of the solar system and the orbital motion of the earth* (10.0).

Major A. G. CHURCH, D.S.O.—*Recent developments in television* (10.30).

Visit to Messrs. Taylor, Taylor and Hobson's Optical Works.

PAPERS OF INTEREST TO THOSE ENGAGED IN TECHNICAL PHYSICS (A‡).

Friday, September 8.

Mr. H. WARREN.—*The talking film in industry* (11.0).

Mr. L. J. DAVIES.—*Hot cathode gas discharge tubes* (11.40).

A description of various types of industrial hot cathode discharge tubes such as 'Thyratrons,' gas discharge lamps, etc., with particular reference to the design of cathodes for various applications.

Mr. J. T. RANDALL.—*Spectroscopy in the service of industry* (12.20).

Monday, September 11.

Dr. C. H. SPIERS.—*Some physical problems of leather manufacture* (12.0).

Mr. H. BRADLEY.—(1) *A study of water absorption and vapour absorption by leather and other shoe materials, with a note on the importance of these processes in shoe manufacture.*

Solutions of the diffusion equation with various boundary conditions and their application to experiments with leathers immersed in water or exposed to various atmospheric humidities. Absorption isotherms —absorption hysteresis—air permeability—porosity—the relation of these properties to the absorption and adsorption processes. Absorbed moisture and thermal conductivity.

The importance of this work in modern shoe factory development.

(2) *The testing of flexible sheet materials by hydrostatic or pneumatic pressure.*

A discussion of the method of test as applied to paper, textile fabrics, metal foil and sheet, leather, rubber, and a presentation of experimental results and calculations bearing on the theory of the subject.

Tuesday, September 12.

DISCUSSION on *High voltages and high vacua* (10.0) :—

Mr. C. R. BURCH.—*On the design and operation of oil condensation pumps.*

The operation of a condensation pump on low vapour pressure organic fluids, such as vacuum distillates from mineral oils, is influenced by considerations which do not arise when mercury is used as working fluid.

The necessity for avoiding 'cracking' restricts the maximum temperature and the pressure of the vapour stream, and the fact that the oil wets the pump surfaces prevents the use of small clearances between cowl and condensing tube. It is therefore not possible to use such pumps against a high fore vacuum pressure. Consideration of the properties of a pump as a vacuum fractionating column shows that the extent to which the final vacuum is influenced by impurities of small amount (1 in 10^6) may depend markedly on whether the condensing surface is water-cooled or not, even though a water-cooled trap is placed between the pump and the fine system. Similar considerations show that it is not advisable to cool the fore vacuum pipe. It is necessary to constrict the pump mouth above the cowl, to condense the 'reverse jet' due to multiple collisions: this theoretical point appears to have escaped notice so long as mercury was the only working fluid used.

Contamination of the working fluid by mercury has been found to be an insidious cause of trouble, so that it is desirable to modify one's technique of performing various experiments—*e.g.* speed measurements—so as to avoid the use of mercury. It is in any case undesirable to use McLeod gauges in oil condensation pump systems, as the readings are no criterion that the pump is working properly. It is necessary to bake out an ionisation gauge before an oil condensation pump will produce a really good vacuum in it; it is difficult to say how much this is a question of outgassing the gauge, and how much a question of indirect 'conditioning' of the pump.

Mr. B. L. Goodlet and Mr. A. Beetlestone.—*The production of high voltages.*

The paper deals with the production of small powers at high voltages for general laboratory purposes, and particularly for use in connection with high vacuum equipment.

Such high voltages may be either unidirectional or alternating. Unidirectional voltages may be continuous pulsating or impulsive; alternating voltages may be damped or undamped and of high or low frequency. The paper outlines the characteristics and methods of producing these various types of high voltage, and gives details of equipment available.

Dr. T. E. Allibone.—*High voltage vacuum tubes.*

This paper deals with the construction of vacuum apparatus suitable for operation at high voltages, such as electron and positive ion discharge tubes, oscillographs, thermionic rectifiers, three electrode valves, and X-ray tubes.

The apparatus described is primarily intended to be continuously evacuated, and demountability is one of its special features, so facilitating experimental work and the replacement of defective parts. Even for high voltage experiments the oil diffusion pumps are operated without the use of liquid air traps, thus allowing big pumping speeds to be attained. Examples of high voltage vacuum tube pumping systems are given.

Dr. J. D. Cockcroft.—*A high voltage D.C. generator.*

In order to produce high speed atomic particles for work on nuclear transformations, it has been necessary to develop sources of steady potential of seven or eight hundred kilovolts, capable of producing currents of several milliamperes, and to develop vacuum tubes to withstand these potentials. Transformers capable of providing these potentials are bulky and expensive, and difficulties arise in applying such transformers directly to a chain of rectifiers. A voltage multiplier has therefore been devised which will

multiply a transformer potential by a factor whose magnitude depends simply on the number of condensers and rectifiers employed, the final output being a potential hav.ng a ripple of only a few per cent. A tower of glass cylinders evacuated by an oil diffusion pump constitutes the four rectifying units employed in the 700,000-volt generator at the Cavendish Laboratory.

The general principles underlying the design of vacuum tubes for these voltages are discussed.

Dr. R. J. van de Graaff.—*Engineering possibilities of electrostatics with vacuum insulation.*

An electrostatic force requires merely the presence of electric charges, whereas an electromagnetic force requires in addition the continuous motion of the charge. This movement of the large charges necessary for electromagnetic force inevitably causes certain difficulties, fundamentally limiting the efficiency, compactness and lightness of electromagnetic machinery. These difficulties can be eliminated by the use of electrostatic rather than the usual electromagnetic force, provided that a suitable insulating medium is available for the high voltages and gradients required.

Certain experimental evidence supports the belief that high vacuum has the desired insulating properties, and that it can be suitably produced for large electrostatic machinery. Assuming that the above evidence is correct in showing that vacuum insulation can be made to prevent electrical breakdown, designs for electrostatic generators and motors are given, with calculations showing that they would have a greater power output per unit of size and weight, with energy losses many times less than present electromagnetic machinery.

Prof. W. Cramp.—*Axial spin of a magnetic field.*

At the end of the year 1831 Faraday carried out a series of experiments upon the effects of the relative motion of a conductor and a magnetic field. He concluded that the moving conductor was the seat of the e.m.f., and that there was ' a singular independence of the magnetic field and the bar in which it resides.' Subsequent writers, however, are at variance as regards the relationship between a permanent bar magnet and its field, some taking the view that when such a magnet is given an axial spin its field moves with it, and others that the field is structureless, and that rest or motion as applied to it are meaningless.

In an attempt to resolve this problem, the author has carried out a long series of experiments, not only upon conductors and magnets, but also upon conductors and solenoids. The results are in some instances unexpected, but in general lead to the conclusion that a spinning magnet and a spinning solenoid behave in an exactly similar manner, and that in no circumstances can the magnetic field of a cylindrical bar magnet be regarded as rotating with the bar in an axial spin. Further, it appears to be impossible to cause a turning moment about the axis of such a magnet by means of current-carrying conductors lying in its magnetic field. In short, while the mechanical effects upon conductors carrying currents and lying in a field leave little doubt as to a connection between the current and the material of the conductor, there is no evidence of a similar attachment between a magnet and its field.

Afternoon.

Visit to University College, Nottingham. Meeting in Physics Department, with papers by members of the department.

Wednesday, September 13.

Visit to Messrs. Taylor, Taylor and Hobson's Optical Works, Leicester.

DEPARTMENT OF MATHEMATICS (A*).

Thursday, September 7.

Dr. E. H. Linfoot.—*On the dissection of large numbers* (11.0).

Much of the recent work in the theory of numbers has been concerned with the representation of a positive integer as a sum of integers of specified type. The Waring and Goldbach problems are of course the outstanding examples, but there are several others of a less formidable nature which are of considerable interest. One of these is the representation of a number as the sum of kth power-free numbers (numbers not containing any kth power greater than 1 as a factor); this problem yields up its main results to purely arithmetical arguments, though there are some cases in which the Winogradoff method, based on the Farey dissection of an interval, is needed to obtain the sharpest error terms.

The theorems discussed are all of purely arithmetical nature. The following are two examples. (1) We ask whether every sufficiently large number can be dissected into, say, a square and a quadratfrei number. Estermann showed that it can, and gave an asymptotic formula for the number of dissections. We then ask whether the dissection can still be made if the two parts are restricted to be 'almost in a given ratio'—that is to say, whether for all n greater than some number n_0 the equation

$$n = m^2 + q \ (q = \text{quadratfrei})$$

always has a solution satisfying

$$m^2 = \lambda_1 n + O(n^{1-\beta})\,; \quad q = \lambda_2 n + O(n^{1-\beta}),$$

where $\lambda_1, \lambda_2 > 0$; $\lambda_1 + \lambda_2 = 1$; $0 \leq \beta < 1$. It will be shown that such is the case provided $\beta < \frac{1}{6}$, and an asymptotic formula for the number of representations will be given.

(2) A similar theorem holds for dissections into two quadratfrei numbers almost in a given ratio; in this case the asymptotic formula is valid and significant for all values of β in the range $(0, 1)$.

Dr. L. S. Bosanquet.—*The absolute summability of Fourier series* (11.30).

A series Σa_n is said to be *absolutely summable* (A) if $\Sigma a_n x^n$ converges to $f(x)$ for $0 \leq x < 1$ and $f(x)$ is of bounded variation in $(0, 1)$. The sum is then $\lim_{x \to 1-0} f(x)$.

The Fourier series of an even function $\varphi(t)$, integrable L, is absolutely summable (A) to zero at the point $t = 0$ if, for example,

(1) $\varphi_\alpha(t)/t$ is integrable L in $(0, \eta)$ for some $\alpha \geq 0$, or

(2) $\varphi_\alpha(t)$ is of bounded variation in $(0, \eta)$ for some $\alpha \geq 0$, and $\varphi_\alpha(t) \to 0$ as $t \to 0$, where

$$\begin{cases} \varphi_\alpha(t) = \dfrac{\alpha}{t^\alpha}\displaystyle\int_0^t (t-u)^{\alpha-1}\,\varphi(u)du, \ \alpha > 0, \\ \varphi_\alpha(t) = \varphi(t). \end{cases}$$

The second condition includes the first. Special cases were given by J. M. Whittaker and B. N. Prasad.

Σa_n is said to be *absolutely summable* (C, α) if $\Sigma \mid S_n^\alpha - S_{n-1}^\alpha \mid$ is convergent, where S_n^α is the α-th Cesaro mean of $S_n = a_0 + \ldots + a_n$. The sum is then $\lim_{n\to\infty} S_n^\alpha$, and the series is also absolutely summable (A).

By employing absolute summability (C) more precise results may be obtained for Fourier series. In particular, (2) is necessary and sufficient for absolute summability (C) of an unspecified order.

Dr. A. C. Offord.—*Fourier and Hankel transforms* (12.0).

Two functions $f(x)$ and $F(x)$ are said to be Fourier cosine transforms of one another when they are connected by the formulæ

$$(1) \qquad F(x) = \left(\frac{2}{\pi}\right)^{\frac{1}{2}} \int_0^\infty \cos xu f(u)\, du,$$

$$(2) \qquad f(x) = \left(\frac{2}{\pi}\right)^{\frac{1}{2}} \int_0^\infty \cos xu F(u)\, du,$$

where the integrals may be either integrals of the classical kind or integrals in some generalised sense.

More generally $f(x)$ and $F(x)$ are Hankel transforms of one another when they are connected by the relations

$$F(x) = \int_0^\infty \sqrt{(xu)}\, J_\nu\, (xu)\, f(u)\, du,$$

$$f(x) = \int_0^\infty \sqrt{(xu)}\, J_\nu\, (xu)\, F(u)\, du,$$

where $J_\nu(z)$ is Bessel's function and $R(\nu) \geq -\frac{1}{2}$. When $\nu = -\frac{1}{2}, \frac{1}{2}$ these reduce to the cosine and sine transforms respectively.

For simplicity we will first state the results for the special case of the cosine transform. We say that $f(x)$ belongs to the class H if

$$(H) \qquad \left| \int_0^w \left(1 - \frac{u}{w}\right) \cos xu\, f(u)\, du \right| \leq M,$$

for all w and x, M being an absolute constant. This condition will obviously be satisfied when $f(x)$ is absolutely integrable in $(0, \infty)$. We show that every function of H has a cosine transform which is bounded. More precisely we prove that, when $f(x)$ belongs to H, the integral (1) is summable $(C, 1)$ almost everywhere to $F(x)$ and (2) is summable $(C, 2)$ almost everywhere to $f(x)$.

Now consider the converse problem. Let $F(x)$ be a bounded function and let it be such that the integral

$$\left(\frac{2}{\pi}\right)^{\frac{1}{2}} \int_0^\infty \frac{\sin xu}{u} F(u)\, du,$$

which is known to exist in the $(C, 1)$ sense, is uniformly summable $(C, 1)$ to an indefinite integral. So that we can almost always write

$$\mathcal{J}(x) = \left(\frac{2}{\pi}\right)^{\frac{1}{2}} \frac{d}{dx} \int_0^\infty \frac{\sin xu}{u} F(u)\, du.$$

When this is the case we say that $F(x)$ belongs to the class B^* and we take $\mathcal{J}(x)$ to be its cosine transform.

We can now state our results as follows :

(i) A function of H has a cosine transform in B^*,
(ii) A function of B^* has a cosine transform in H.

Suppose now that $f(x)$ belongs to H and is bounded. Then we show that its transform $F(x)$ belongs to H. Hence there is a class HB, consisting of all the bounded functions which belong to H, which is such that the cosine transform of a function of HB belongs also to HB.

These results hold also for Hankel transforms. We say that $f(x)$ belongs to H_ν if

$$\left| \int_0^w \left(1 - \frac{u}{w}\right) \sqrt{(xu)}\, J_\nu(xu) f(u)\, du \right| \leq M$$

for all x and w. There is a corresponding definition of the class B_ν^*, and there is a symmetrical class $H_\nu B$ as in the case of the cosine transform.

We can now apply the analysis of Hardy and Titchmarsh (*Quart. Journal, Ox. Series*, i, pp. 196–231) to find the class of all the functions of $H_\nu B$ which are their own Hankel transforms. We obtain, in fact, the following result.

A necessary and sufficient condition that a function $f(x)$ of $H_\nu B$ should be its own Hankel transform is that it should be of the form

$$f(x) = \frac{1}{2\pi} \int_{-\infty}^{\infty} \chi(t)\, x^{-\frac{1}{2}-it}\, dt,$$

where the integral is summable $(C, 1)$ almost everywhere, and $\chi(t)$ is such that

$$\left| \int_{-T}^{T} \left(1 - \frac{|t|}{T}\right) \chi(t)\, x^{-\frac{1}{2}-it}\, dt \right| \leq M,$$

for all $T \geq 0$ and $x \geq 0$; and

$$\frac{\chi(t)}{2^{\frac{1}{2}+\frac{1}{2}it}\, \Gamma\left(\frac{1}{2} + \frac{1}{2}\nu + \frac{1}{2}it\right)} = \text{even function of } t.$$

Putting $\nu = -\frac{1}{2}$, we get the necessary and sufficient condition for a function to be its own cosine transform.

It is possible to extend the theory for cosine transforms to functions of several variables.

Friday, September 8.

Mr. W. V. D. Hodge.—*Abelian integrals attached to algebraic varieties* (11.0).

G. Mannoury has shown how a complex projective plane can be represented as a closed four-dimensional locus in Euclidean space in such a way that many projective properties of the plane can be represented as metrical properties of the locus. His method can be extended to algebraic varieties of any number of dimensions, and in this way we can obtain a representation of the Riemannian manifold of an algebraic variety of m dimensions as a locus of $2m$ dimensions in a Euclidean space. The differential form

$$g_{ij}\, dx^i\, dx^j$$

which gives the element of length on this locus has many interesting pro-

perties, when considered according to the general theory of quadratic differential forms.

It can be shown that the anti-symmetric tensors $B(i_1 \ldots i_p)$ which satisfy the equations

$$\sum_{r=1}^{p+1} (-1)^{r-1} B(i_1 \ldots i_{r-1} i_{r+1} \ldots i_{p+1}, i_r) = 0$$

$$g^{rs} B(i_1 \ldots i_{p-1}, r, s) = 0$$

and which are finite everywhere on the manifold are all linear combinations with constant coefficients of R_p independent tensors, where R_p is the p-th Betti number of the manifold, and that the integrals formed from these

$$\int B(i_1 \ldots i_p)\, dx^{i_1} \ldots dx^{i_p},$$

which are called harmonic integrals, cannot be without periods. It is usual to take $z^1, \ldots, z^m$ as the complex parameters on the variety, and writing

$$z^r = x^r + ix^{m+r},$$

we take $x^1, \ldots, x^{2m}$ as the real parameters on the manifold. Then among the harmonic integrals are included the real and imaginary parts of the Abelian integrals (of the first kind)

$$\int P(i_1 \ldots i_p)\, dz^{i_1} \ldots dz^{i_p}$$

attached to the variety. A study of the harmonic integrals leads to many new and interesting properties of the Abelian integrals, some of which are described.

Dr. D. W. Babbage.—*Cremona transformations* (11.30).

If V_k is a rational k-dimensional locus in space S_n, of n dimensions, which can be birationally projected from each of two $[n-k-1]$'s, Π_1 and Π_2, then we can use V_k to set up a Cremona (1, 1) correspondence between two $[k]$'s, $S_k^{(1)}$ and $S_k^{(2)}$, taken in general position in S_n, two points, P_1, P_2, of these spaces corresponding when the $[n-k]$'s, which join Π_1 to P_1 and Π_2 to P_2 respectively, meet V_k in the same point P. Segre has obtained Cremona transformations of ordinary space arising by two projections in this way from rational scrolls of planes, and Marletta has given a simple method by which any Cremona transformation T can be interpreted in terms of two projections of a locus of higher space; but apart from the work of these, little has been done by hyperspatial methods.

In the present paper these methods are used to give a simple interpretation and classification of the so-called rational and elliptic Cremona transformations of ordinary space S_3, the genus of a Cremona transformation of S_3 being defined with Loria as the genus of the general plane section of a general member of one of the two homaloidal systems of the transformation, a number which is an invariant of the transformation. The question of resolving a Cremona transformation T into the product of several simpler transformations is often simplified when T is given a hyperspatial interpretation; for example, the known fact that all the rational Cremona transformations of S_3 can be built up from quadro-quadric Cremona transformations is rendered practically self-evident.

Dr. P. Du Val.—*Multiple planes* (11.50).

A multiple plane of n sheets may be defined as the projective image of a rational involution of sets of n points on an algebraic surface. It has a

branch curve, locus of images of sets in which two points coincide, which has a cusp for each set in which three points coincide, and a node for each set in which four points coincide by pairs. The arithmetic genus of a multiple plane is given by

$$p_a + 2 = \tfrac{1}{2}(\beta - 1)(\beta - 2) + n - \varkappa - \delta$$

where n is the number of sheets, 2β the order of the branch curve, $3\varkappa$ the number of its cusps, and 4δ that of its nodes.

Double planes form a class of surfaces somewhat analogous to hyperelliptic curves, in having a rational involution of pairs of points ; the analogous property holds, that the canonical system belongs to the involution.

A double plane can have as branch curve any curve of even order, but for $n > 2$ the branch curve must have some cusps and (for $n > 3$) nodes in order that the surface may exist at all.

A topological condition (of presence and arrangement of cusps and nodes) on the branch curve for the existence of a multiple plane exists but is not easy to apply.

By comparatively simple algebraic methods, however, it is possible to enumerate all the cases that can arise with branch curves of reasonably low order.

Mr. J. H. C. Whitehead.—*On the calculus of variations in the large : loci of conjugate points* (12.10).

Let V_n be an analytic manifold with a positive Finsler metric

$$ds^2 = g_{ij}(x, dx)\, dx^i\, dx^j,$$

the g's being homogeneous of degree zero. By minimising the integral $\int ds$ we obtain a family of extremals. Each extremal through a given point O may be regarded as the image, possibly the singular image, of a straight line through a point (o) in a Euclidean space, E_n. As when setting up a normal co-ordinate system one can vary the straight line through (o) and so represent V_n as the image of E_n in a single-valued analytic transformation $E_n \to V_n$. The points in E_n at which this transformation fails to be locally (1–1) correspond to the points in V_n, which are conjugate to O. They constitute an analytic complex K_{n-1}. The object of this paper is to study the complex K_{n-1} and the nature of the transformation $E_n \to V_n$ near points on K_{n-1}.

Mr. H. G. Green.—*Pascal's Theorem in n dimensions* (12.30).

The paper describes the work of the author and a colleague on an application, which is still in progress, of the theory of involutions of restriction 1 to a generalised Pascal figure. The methods used are a development from those of Pomey, which give opportunity for a closer discussion of special cases. The methods of the extension are illustrated by details of the figure in three dimensions, in which the place of the two dimensional Pascal line is taken by a series of closed networks of lines and the projective connection with the plane figure is established. In the general n dimensional case it is shown that it is only for special forms of n that a symmetric figure can be constructed, and that the networks are then of two types, open and closed.

Tuesday, September 12.

JOINT DISCUSSION with Section J (Psychology, *q.v.*) on *The validity and value of methods of correlation* (10.0).

DEPARTMENT OF COSMICAL PHYSICS (A†).

Thursday, September 7.

Dr. W. H. McCREA.—*Problems of the solar chromosphere and corona* (11.0).

Survey of recent work, particularly Rosseland's theory depending on the ejection of fast electrons by the sun. The possibility of such ejection.

Mr. W. M. H. GREAVES.—*The observation of stellar colour temperatures* (11.25).

Dr. G. C. McVITTIE.—*Non-static solutions, with singularities, of Einstein's gravitational equations* (11.50).

Generalisation of Schwarzschild's solution for a mass-particle, in the expanding universe theory. The choice of co-ordinate systems. The distribution of matter outside the mass-particle. The cosmical constant.

Dr. W. J. S. LOCKYER.—*Periodic changes in two Be-type spectra* (12.15).

One of the researches which is being carried out at the Norman Lockyer Observatory at Sidmouth is the spectroscopic study of some of the brighter stars of the Be type—i.e. those stars which exhibit bright hydrogen lines in their spectra. This work was commenced in the year 1923, and has been continually pursued since then.

The Sidmouth research has been chiefly confined to the determination of the changes in the relative intensities of the bright components of each of the hydrogen lines, for each hydrogen line consists of a broad absorption band on which are superimposed two bright lines, separated by a strong sharp absorption line. These intensity differences are determined by two methods—one by eye-estimates under a small magnifying power ($\times 2$), and the other by a wedge-micrometer. The results are here given for two stars only, to illustrate the methods. The first deals with the star φ Persei, of magnitude 4·19, for which a period of change of 126·8 days is deduced. The character and intensities of several absorption lines in the spectrum are also discussed. The second star, γ Cassiopeiæ (mag. 2·01), is a star the spectrum of which has never before been detected to exhibit any change. Distinct variations are here indicated, and a probable variation of about four years in length is clearly indicated.

Mr. A. D. THACKERAY.—*The measurement of line intensities in stellar spectra* (12.40).

Stellar spectra for the measurement of line intensities have to be standardised photometrically in order to relate the photographic density to the intensity of the original incident light. Many photographic errors may arise due to differences in stellar and standard exposures, and especially to

Eberhard effect. The microphotometer will introduce further errors, but the largest errors of all probably arise in the final process of reducing the microphotometer tracings, the difficulties of drawing in the continuous background and eliminating blends being often insuperable. With spectrographs of ordinary dispersion, an error of 20 per cent. is to be expected in many cases. This seriously limits the usefulness of such observations in deriving values of atmospheric pressures, compositions and opacities, and of stellar rotations.

EVENING.

Prof. F. LINKE.—*Cloud evolution* (with cinematograph demonstration, 8.30).

Tuesday, September 12.

Mr. A. GRAHAM.—*The instability of air layers* (10.0).

Walker and Phillips have shown that the vortex patterns produced, when a thermally unstable layer of air is subjected to a double shear, show close similarity to certain cloud formations in the sky ; in the sky, however, there is ordinarily a single shear. The paper describes some experiments with an unstable layer subjected to single shear.

The upper surface of the experimental channel was a long strip of plate glass ; it was drawn steadily over a short, hot iron plate, thus producing a single shear in the air layer between them. As in the double shear experiments straight vortices could be formed, aligned either transversely to or along the shear ; in addition, there were formed a square pattern having one set of diagonals along the shear, and some transitional patterns ; hexagons were obtained without shear and also with a certain value of the shear. There is a steady change from hexagons into longitudinal rolls through the other patterns. All these patterns have their counterpart in the sky.

An investigation was made into the patterns formed in the absence of shear. If the lower surface of an air layer is rapidly warmed, cells having ascending air at the centres are produced ; if the upper surface is rapidly cooled, the cells have descent in the centres. In the sky cells are formed having ascent in the centres and also cells with descent, thus it appears that they should be formed under the above conditions. If in the laboratory the temperature difference between the top and bottom surfaces of an air layer is large the cells have descent in the centres, whereas with a liquid layer the cells have ascent ; this phenomenon is apparently due to the fact that the cool upper surface of an air layer has a lesser viscosity than the warm lower surface and is therefore less stable, while for a liquid it is the reverse.

The experiments considerably strengthen the theory that many cloud patterns are due to thermal instability and not to Helmholtz waves.

Mr. E. TILLOTSON.—*High focus earthquakes in the International Seismological Summary* (10.20).

From June 1914 to March 1928 there were twenty-four so-called shallow focus earthquakes, whilst there were about three times as many deep focus earthquakes and approximately 11,000 normal tremors published in the International Seismological Summary. One of the ' shallow ' focus earthquakes had a focus 0·04 of the earth's radius above normal, and so it has been suggested for this and other reasons that the normal depth of an earthquake is about 160 miles below the surface. More recently, however,

Dr. Harold Jeffreys and others have shown that the normal depth of an earthquake is at the base of the granitic layer, or about 11 miles deep.

There is no peculiarity in the periodicity of these ' shallow ' focus earthquakes, nor is there any system about the position of their epicentres in the earth's surface. Also when the seismograms for such tremors are examined they appear to be perfectly normal, and the L phase is not unduly large.

At Oxford the epicentres of all earthquakes are determined from the S–P differences, using Zöppritz-Turner tables, and a shallow focus earthquake is one which calls for a removal of the epicentre so determined away from *all* observing stations, no matter what their azimuth. In other words, if the P phase arrives at its correct time, then S appears to arrive late.

Travel-time graphs have been drawn and calculations made for all the readings for all the ' shallow ' focus earthquakes separately, and from these it appears that the P wave is quite normal and always well observed, whilst the true S by Jeffreys's tables is practically absent, and the readings usually given for S approach more nearly to the Gutenberg PS curve. Several seismograms have been examined, and in all these P, PP, PPP, and PS waves are discernible, but S and SS are either extremely doubtful or absent altogether.

Conclusions.

1. The peculiarity of the so-called ' shallow ' focus earthquakes appears to be due to the absence or doubtful presence of the true S pulse on all the seismograms, though the PS pulse is present and has been usually identified as S.

2. Too great praise cannot be bestowed on the work of the International Seismological Summary at Oxford, and it seems advisable to continue to print *all* the readings sent by observing stations.

3. More reliance may be placed on the general identification of the P than the S pulse, though it is important to have good tables for P and S separately. These are confidently expected when Dr. Jeffreys has completed his present work on his new tables.

4. The fine adjustment of epicentres might with advantage be carried out with P readings alone.

5. It is advisable to have field evidence with regard to an epicentre wherever possible in addition to the evidence of seismograms.

Rev. J. P. Rowland, S.J.—*The Wensleydale earthquake of 1933, January 14* (10.40).

On January 14, 1933, at about 8.30 A.M. G.M.T., an earthquake shock was felt over a large area in the north of England, and was recorded at all the British seismological stations, and at a few on the Continent.

By collation of all the newspaper reports and a few private advices—about a hundred reports in all—a seismic map was drawn, which gave a series of isoseismals ranging from 7 to 2 on the Rossi-Forel scale, the highest enclosing a small area round Upper Wensleydale, and the lowest an area of about 25,000 square miles, extending from near Berwick-on-Tweed to Anglesea, and from the Isle of Man to some distance in the North Sea off the Yorkshire coast. The disturbed area is about the average given by C. Davison for British earthquakes of central intensity 7.

Measurement of the P* and S* phases on the seismograms of the three nearest observatories, Stonyhurst, Durham, and Bidston, gave the position of the epicentre as 54° 20′ N., 2° 18′ W., which is at the head of Wensleydale, about one mile to the N.E. of Hawes Junction railway station. Reference

to the Ordnance Survey geological map of the area shows that this position lies on a fault which runs for about two miles in a north-easterly direction from the head of the Dale.

From this epicentre distances were calculated to all the observatories—11 in number—from which records were available, and a time-distance diagram was plotted for all the points measured on the seismograms. From this the travel-times, velocities and apparent delays in starting of the six phases exhibited in the following table were deduced. The values obtained by Dr. Harold Jeffreys for two previous British earthquakes are given for comparison.

	Wensleydale.		Jeffreys.	
Phase.	Vel. km./sec.	Delay. sec.	Vel. km./sec.	Delay. sec.
P	8·55	11	7·8	9
P*	6·21	2	6·3	5
Pg	5·23	6	5·4	3
S	4·29	10	4·35	8
S*	3·54	0	3·7	4
Sg	3·30	4	3·3	0

It will be noted that whilst the velocity of the Sg wave is identical with that previously found, that of the P wave is appreciably higher, and all the rest are slightly lower than the normal. The apparent times of starting also follow a different order. These anomalies may be related to depth of focus, which appears to have been somewhat greater than normal. In determining the epicentre from the three nearest stations, it was found impossible to obtain intersecting circles by adopting the velocities appropriate to Pg and Sg, but good concordance was obtained by taking those of P* and S*.

It should be stated that at all the stations except Stonyhurst and Durham the movements recorded were extremely small, rendering measurement and identification of phase difficult, so that any conclusions arrived at can only be taken with some reserve. The points measured, however, lie very well on the straight lines corresponding to the values in the above table, which accordingly seems to be fairly well established.

Mr. A. C. Best.—*Temperature gradients near the ground* (11.0).

A paper was read at the British Association Meeting in 1925 by N. K. Johnson, describing the results obtained from a study of the vertical gradient of temperature in the atmosphere over the height interval 1·2 m. to 17·1 m. These results were subsequently amplified and published as a Geophysical Memoir by the Meteorological Office.

The apparatus used by Johnson has remained in use since that date, and in 1931 additional apparatus was erected by the author with a view to examining the temperature gradient below 1·2 m.

Records of the temperature differences over the height intervals 2·5 cm. to 30 cm. and 30 cm. to 120 cm. over close cropped grass have been obtained for approximately two years by means of thermocouples. The results have been analysed to give mean values corresponding to clear and overcast skies. The greatest values of the temperature differences for each month are also given, the maximum values of the lapses found for the lowest interval being of the order of one thousand times the dry adiabatic lapse rate.

Some temperature-height curves for the height interval 2·5 cm. to 17·1 m. are given, and the time of maximum temperature at various heights is discussed.

DISCUSSION on *Condensation of water in the atmosphere* :—

Dr. G. C. SIMPSON, C.B., F.R.S.—*Problems of the condensation of water in the atmosphere* (11.20).

A simple straightforward description of the physical processes involved in the condensation of water in the atmosphere leading up to precipitation would appear to be as follows :

The nuclei of condensation are hygroscopic particles, mainly sea salt. These collect water and grow in size with increase of relative humidity, but remain invisible even in saturated air except as a haze. When air is cooled below the dewpoint, water is deposited on the nuclei, and a mist, fog, or cloud is produced. Continued cooling (within ascending air currents) causes growth of cloud particles, until their increased size, augmented by collisions, results in rain.

This simple statement will be considered in the light of the following difficulties or problems :

(*a*) Köhler's statement that if ρ is the concentration of salt in water derived from clouds (grams per litre), then $\rho = \rho_0 2^n$ in which ρ_0 is a constant and n is an integer.

(*b*) Köhler's similar but quite unrelated statement, that if v is the volume of a cloud particle, then $v = v_0 2^n$ in which v_0 is a constant and n is an integer.

(*c*) Why do some clouds rain and others not ?

(*d*) Is coagulation caused by (1) the relative motion of drops of different size, (2) the turbulent motion of the atmospheres, (3) electrical charges ?

(*e*) Bergeron's statement that no rain (other than fine drizzle) occurs without the presence of snow in the upper part of the cloud—the melting snow-flakes being the origin of the raindrops.

(*f*) Do certain sizes of raindrops occur more frequently than others, as first suggested by Defant, and later by Köhler and Niederdorfer ?

(*g*) The part played by radiation in fog.

(*h*) The diurnal variation of fog. Is Entwistle's explanation of the high frequency of fog just after sunrise satisfactory ? (*Jour. Roy. Aeronautical Soc.*, 1928).

(*i*) Optical phenomena show that spherical cloud particles occur at very low temperature—e.g. cirro-cumulus clouds, fogs in polar regions, etc. What is the physical state of these particles ? They cannot be supercooled water because they appear in air masses, the temperature of which is always far below the freezing-point, and it is difficult to see why sublimation should not build up crystals at such low temperatures.

Mr. H. L. GREEN.—*A critical study of direct methods for determining the number and size-frequency of particles in aerosols* (11.40).

The ranges of sizes of particles found amongst atmospheric nuclei, dusts, fogs, clouds and other aerial disperse systems are considered, and direct methods for determining the number and size-frequency of such particles are critically examined. The study is confined mainly to condensation (Aitken), photographic, microscopic, ultramicroscopic and other optical methods, particular attention being paid to the accuracy and limitations of each method.

Prof. J. J. NOLAN and Mr. J. P. RYAN.—*Discharge from a raindrop in an intense electric field* (12.0).

When a drop is exposed to an intense electric field, it becomes pulled out and begins to discharge. Negative discharge is greater than positive

and occurs at lower field values. The onset of discharge is determined by the approximate relation $F\sqrt{r} = 3{,}600$, where F is the uniform field in volts/cm. and r the radius of the drop.

In ordinary atmospheric air the ions discharging from the drop attach themselves to condensation nuclei and form large ions. But in pure air, ordinary small ions only are found. No production of large ions or nuclei can be detected even when a drop is discharging up to 55 micro-ampères and is being visibly broken up by the discharge.

It would appear, therefore, that the low mobility ions required by C. T. R. Wilson's theory of thunderstorm electrification are not directly produced by discharge from raindrops.

Mr. L. H. G. Dines.—*Observations of supersaturation of water in the free atmosphere, and an example of a cumulus cloud composed of supercooled water drops* (12.20).

A number of observations of relative humidity in the upper air over England are summarised, made with sounding balloons carrying recording meteorographs. The conclusion is reached that on many occasions, in clouds, a state of supersaturation of water vapour exists. It is suggested that the degree of this supersaturation may often exceed a relative humidity of 120 per cent.

SECTION B.—CHEMISTRY.

Thursday, September 7.

Presidential Address by Prof. R. Robinson, F.R.S., on *Natural colouring matters and their analogues* (10.0). (See p. 45.)

Discussion on *Natural colouring matters* (11.0) :—

Prof. Dr. R. Kuhn.—*Carotenoids and flavines.*

In recent years many new natural colouring matters of the carotene-group have been discovered, and a general view is given of their genetical relationships. The first products of synthesis in plants are the dyestuffs with 40 carbon-atoms, from which carotenoids, containing fewer carbon-atoms, are produced by oxidative disintegration. The splitting of the carbon-chains may occur in different ways :—

(1) $C_{40} \longrightarrow C_{20} + C_{20}$, β-carotene $\longrightarrow$ 2 vitamin A.
(2) $C_{40} \longrightarrow C_{8} + C_{24} + C_{8}$, lycopene $\longrightarrow$ bixin + 2 methylheptenone.
(3) $C_{40} \longrightarrow C_{10} + C_{20} + C_{10}$, proto-crocin $\longrightarrow$ crocin + 2 picro-crocin.
(4) $C_{40} \longrightarrow C_{13} + C_{27}$, proto-azafrin $\longrightarrow$ (ionone) + azafrin.

α-, β- and γ-carotene are provitamins A. The constitution of α- and γ-carotene is asymmetric; they supply only 1 mol. of vitamin A, and therefore their physiological activity is only half that of the symmetrical β-carotene.

Widely distributed in nature are certain water-soluble dyestuffs, coloured yellow and fluorescing intense green. They have been called flavines. Ovoflavine from egg-albumin and lactoflavine from milk have been prepared

by Th. Wagner-Jauregg in crystalline condition. The elementary analysis suggests the formula $C_{17}H_{20}N_4O_6$. According to the experiments of P. György, lactoflavine, three times recrystallised (m.p. 267°), promotes normal growth, when administered in doses of 5 γ daily to rats deprived of vitamin B_2.

The properties of flavines (lyochromes) and of carotenes (lipochromes) are in many respects complementary.

	Lyochromes.	Lipochromes.
Solubility	Soluble in water	Insoluble in water
Colour	Yellow, orange	Yellow, orange, red
Fluorescence	Green (very strong)	Yellow-green (weak)
Combined with	Proteins, polysaccharides	—
Composition	Containing nitrogen	Nitrogen-free
Acids	Resistant	Labile
Alkalies	Labile	Resistant
Oxidation	Resistant	Labile
Biologically related to	Vitamin B_2 and enzymes	Vitamin A
Effective daily dose	5 γ lactoflavine	5 γ α- or γ-carotene 2·5 γ β-carotene

The flavines can be reversibly reduced (flavine + 2H ⇄ leuco-flavine), and therefore they act in the cell as transporters of oxygen. When combined with carriers of high molecular weight, they appear to act more strongly as enzymes (O. Warburg). Apparently the flavines are exogenous precursors of such oxidation-enzymes (pro-enzymes). The undialysable enzyme-preparations act also as vitamin B_2; the dialysable flavines have no more enzymatic activity; the irradiated flavines, soluble in chloroform, have neither the properties of enzymes nor those of the vitamin.

Flavines.	Activity as Vitamin B_2.	Activity as Enzyme.
(1) Combined with carriers of high molecular weight (undialysable)	+	+
(2) Crystallised dyestuffs (dialysable, insoluble in chloroform) . .	+	−
(3) Crystallised irradiated flavine (soluble in chloroform) . .	−	−

Dr. R. P. Linstead.—*The phthalocyanines: a new class of synthetic colours.*

When phthalimide is heated with certain metals, notably iron and magnesium, in a current of ammonia, a complex reaction occurs with the formation of highly coloured substances of a novel type. These have been named *phthalocyanines* from their origin and deep-blue colour.

Identical compounds may be made from *o-cyanobenzamide* $C_6H_4(CN)CONH_2$ by the action of metals and metallic derivatives, such as oxides, at temperatures of about 250° C. The metal may be eliminated from the magnesium compound by the action of concentrated sulphuric acid to yield phthalocyanine, the parent substance of the group.

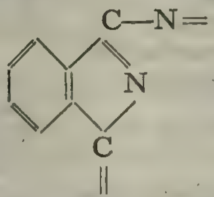
Like indigo and indanthrone, these substances may be purified by crystallisation from boiling quinoline and by sublimation in a vacuum, and may be obtained as homogeneous macrocrystalline blue solids with a fine purple reflex.

Analysis shows them to contain the unit $(C_8H_4N_2)$ combined in their

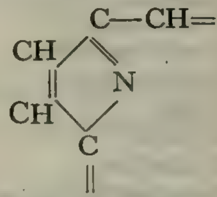
simplest form with a divalent metal or with hydrogen in the manner: $(C_8H_4N_2)_4H_2$ or $(C_8H_4N_2)_4$.metal. The mode of synthesis and the reactions of these compounds indicate that they contain a system of *iso*-indole rings linked by nitrogen atoms and forming a large ring with the metal held in the centre by primary and secondary valencies.

The phthalocyanines exhibit two features of special interest. First, their fundamental unit resembles that of porphin, which is the basis of the naturally occurring pigments of the chlorophyll and hæmin group. The structural unit of the natural pigments differs in containing no benzene ring and in having methine (— CH =) links in place of nitrogen.

Phthalocyanine Unit



Porphin Unit



Secondly, the phthalocyanines are among the most stable of complex organic compounds. For example, the copper compound sublimes unchanged at 600°; dissolves in strong sulphuric acid without decomposition or loss of metal; and resists the action of molten caustic potash. Other compounds of the group show a similar stability.

Dr. N. V. Sidgwick, F.R.S.

The plane arrangement which these formulæ require us to ascribe to the covalencies of the metals they contain is of great interest. According to the theory, a plane distribution of four covalencies of an atom is possible (1) for four of the six covalencies of a 6-covalent atom, (2) for a 4-covalent atom of one of the later transitional elements, such as nickel and perhaps iron. The iron compounds described would then come under (2), and the magnesium complexes could only exist under (1) if the atom was 6-covalent, which would explain why these compounds have two molecules of water.

An interesting test would be to examine the beryllium complexes of these substances. On the theory, beryllium cannot form more than four covalencies, and these cannot lie in a plane, but must be tetrahedral. It should, therefore, be incapable of forming links with four nitrogen atoms in a plane. On the other hand, beryllium co-ordinates with such energy that it will form the complexes if it can; and we could thus discover whether the steric conditions permit of their formation.

Friday, September 8.

Discussion on *Hormones* (10.0):—

Prof. Dr. F. Kögl.—*Plant growth hormones* (*Auxin a and Auxin b*).

(Ordered by the General Committee to be printed *in extenso*. See p. 600.)

Mr. G. A. D. Haslewood.—*Earlier chemical work on œstrin.*

From 1903 onwards, many extracts of ovarian tissue were prepared which could produce œstrus in normal and ovariectomised animals. In 1923, vaginal cornification was adopted by Allen and Doisy as a method of assay.

Ascheim and Zondek in 1927 discovered the hormone in pregnancy urine. The chemical nature of the active substance was partially disclosed by methods of obtaining potent extracts. Its phenolic nature was recognised by Funk and by Marrian in 1929.

Doisy, Veler and Thayer, in 1929, and shortly afterwards Butenandt, and also Dingemanse, isolated crystalline ketohydroxyœstrin, $C_{17}H_{21}(CO)(OH)$. Marrian obtained trihydroxyœstrin, $C_{18}H_{21}(OH)_3$, in 1930.

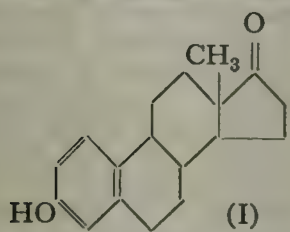
Butenandt, having found both compounds in pregnancy urine, demonstrated that ketohydroxyœstrin was formed by potassium bisulphate dehydration of trihydroxyœstrin, a reaction which Marrian and Haslewood later showed to occur through elimination of the elements of water between the two alcoholic hydroxyl groups of trihydroxyœstrin.

Examination of surface films of œstrin derivatives by Adam and Danielli and a crystallographic investigation by Bernal showed the œstrin molecule to possess a rigid fused-ring structure of the phenanthrene or anthracene type, with the phenolic group remote from the other oxygen-containing groups.

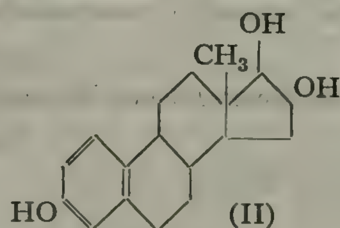
The absence of ethylenic double bonds was shown by the preparation of substituted mono-bromo-derivatives.

Dr. A. Butenandt.—*The relation of the sex hormones to the sterols and bile acids.*

The following constitutional formulæ have been proposed for the follicular hormone, $C_{18}H_{22}O_2$, and its hydrate, $C_{18}H_{24}O_3$:



(I)



(II)

These formulæ are based on the following observations :

(1) The follicular hormone is a hydroxyketone, the hydrate a trihydroxy-compound ; both contain one acidic hydroxyl group, similarly linked in each case, whilst in the hydrate two adjacent secondary alcoholic groups replace the keto-group.

(2) The results of catalytic hydrogenation conjoined with those of the measurement of molecular refraction show decisively the presence in the molecule of only three double bonds. This being established, the hydrogen content as determined by analysis demands a four-ring system.

(3) The three double-bonds confer aromatic character, as shown by their chemical behaviour and in view of the results of measurements of molecular refraction and ultraviolet absorption. The acidity of the phenolic group is to be explained by its phenolic character.

(4) The keto-group or the two hydroxyl groups are in a terminal five-membered ring, which is opened by the alkali-fusion of the hydrate, a dicarboxylic acid $C_{18}H_{22}O_5$ being formed.

(5) The points of union of this ring are shown by the degradation of the acid $C_{18}H_{22}O_5$ to 1 : 2-dimethyl-7-hydroxyphenanthrene and 1 : 2-dimethylphenanthrene.

The formulæ I and II demonstrate a clear connection between the follicular hormone and the sterols, bile-acids, and pregnandiol. This relationship is substantiated by the preparation of degradation products common

to both classes of compounds (e.g. 1 : 2-dimethylphenanthrene from ætiobilianic acid).

The testicular hormone (male sex-hormone), the action of which is demonstrated by the growth of the cock's comb, is a hydroxyketone, $C_{19}H_{30}O_2$, which contains a saturated four-ring system. Its relationship to the follicular hormone and to the sterols has not yet been shown with certainty.

Prof. E. C. DODDS.—*The significance of synthetic œstrogenic compounds.*

Hitherto the œstrus reaction has been regarded as a specific response to œstrin and its derivatives, none of which have as yet been prepared synthetically. In collaboration with Cook it has been shown that compounds of widely differing chemical structure may be synthesised, capable of causing a full œstrus reaction quite indistinguishable from the natural phenomenon. Thus, 1-keto-1 : 2 : 3 : 4-tetrahydrophenanthrene falls into this category, and also 9 : 10-dihydroxy-9 : 10-di-*n*-butyl-9 : 10-dihydro-1 : 2 : 5 : 6-dibenzanthracene. In addition, it has been shown that calciferol will produce œstrus when injected in large quantities, as also the two carcinogenic hydrocarbons 1 : 2-benzpyrene and 5 : 6-cyclopenteno-1 : 2-benzanthracene. It would appear, therefore, that it is possible to have one molecule possessing pharmacological activity of two entirely different varieties. The theoretical importance of these observations is obviously great, since it may mean that the processes of œstrus-production, cancer production and vitamin-D activity are related in some unsuspected manner.

AFTERNOON.

Visit to Messrs. Boots, Nottingham.

EVENING.

Sectional dinner.

Saturday, September 9.

AFTERNOON.

Visit to Ketton Cement Works.

Monday, September 11.

DISCUSSION on *The interatomic distances and forces in molecules* (10.0):—

Dr. N. V. SIDGWICK, F.R.S.

Prof. J. E. LENNARD-JONES.

Dr. J. M. ROBERTSON.—*Interatomic distances in some aromatic hydrocarbons from a Fourier analysis of the X-ray crystal data.*

If X-ray crystal analysis can be carried far enough it yields the most accurate and complete information regarding interatomic distances, and has the great advantage of being applicable to very complicated structures with the same precision as to simple atomic arrangements. Owing to the essentially periodic structure of a crystal, we may represent the electron density by means of a Fourier series

$$\rho\,(x, y, z) = \sum_{-\infty}^{+\infty}\sum_{-\infty}^{+\infty}\sum_{-\infty}^{+\infty} A_{pqr} \cos 2\pi\,(px/a + qy/b + rz/c),$$

assuming a centre of symmetry in the structure. It can then be shown that the coefficients A_{pqr} are proportional to the structure factors of the crystal, which can be determined from experimental measurements of intensity. These measurements, however, do not tell us the phase constant, or sign, which must be attached to each term. These must at present be found by trial and error. In practice a double Fourier series is the most convenient to apply, representing a projection of the structure on a given plane.

Examples of such projections from anthracene, naphthalene and durene were shown. The benzene ring in all these compounds consists of a regular plane hexagon of carbon atoms, the distance between the centres being 1·41 Å. In durene the methyl groups are reasonably spherical, and are situated at 1·47 Å. from the adjacent aromatic centres. These methyl groups are also displaced slightly away from each other, towards the unsubstituted positions of the benzene ring, the displacement being about 3° from the symmetrical or unstrained position.

Dr. J. D. Bernal.

Mr. E. J. Bowen.—*Forces between atoms in molecules.*

The characteristic vibration frequencies of simple molecules can be found from Raman spectra, near infra-red absorption spectra, and from electronic absorption spectra in the visible and ultra-violet region. A diatomic molecule has one characteristic frequency, from which the force constant of vibration can be calculated. More complex molecules have a number of characteristic frequencies which must be assigned to specific modes of vibration. For this purpose use is made of selection rules due to Placzek and to Dennison. In the case of certain simple types of organic molecules (e.g. the cyanogen halides) it is possible to assign frequencies with some degree of reliability by intercomparison of the observed frequencies with those of other molecules, but in general it is necessary to examine the infra-red absorption bands at high dispersion in order to apply Dennison's assignment rules. Such infra-red work at high dispersion has been carried out in few cases at present. When the observed frequencies of a simple molecule such as SO_2 have been correctly assigned to specific modes of vibration, approximate values for the force constants of the links and the apex angle of the molecule can be obtained by treating the molecule as an assemblage of masses and springs. A more refined treatment must take into consideration 'resonance degeneracy' and the anharmonic character of the vibrations. This necessarily means the introduction of many new constants into the problem. A very complete treatment of the vibrations of the CO_2 molecule, allowing for these factors, has recently been given by Adel and Dennison. From the experimental values of the fundamental frequencies (allowing for resonance interaction), of the overtones (which are not the sum of integral multiples of the fundamentals), and of the rotational structure of the vibration bands (which is modified by the vibration), they build up an equation of twelve constants which completely expresses the experimental results. The next development lies in the elimination of many of these constants by the discovery of a suitable potential energy function which will also reproduce the results. Adel and Dennison apply a Morse potential energy function to each of the C=O links in the molecule, and an empirical exponential function to allow for the repulsion of the oxygen atoms for each other. The resulting equation containing four constants is capable in a semi-quantitative way of reproducing the features

of the original twelve constant equation. Further work on these lines is likely in the near future to provide a clearer picture of the interaction within a molecule of atoms which are linked together and of atoms which are not linked in the chemical sense.

Mr. C. N. Hinshelwood, F.R.S.

The curves showing the rate of reaction of certain gaseous substances as a function of pressure have proved to be composite in nature, although only one set of reaction products is formed. Thus it must be concluded that a given molecule can be activated in more than one way for the same chemical transformation. This phenomenon presumably depends upon the localisation of the energy of activation in different modes of vibration, and should be correlatable with the information about the internal structure and vibrations of the molecules, as obtained from other methods of investigation.

Afternoon.

Visit to Messrs. Briggs' Tannery, Leicester.

Tuesday, September 12.

Discussion on *The chemistry of the tanning process* (10.0) :—

Dr. D. Jordan Lloyd.—*The chemistry of skin, and the problem confronting the tanner.*

Animal skin consists of a tissue of fibres which are the biological units. Each fibre has crystalline properties and is formed of packets of elongated molecules between which are planes of weakness. The fibre can be split up at these planes into fibrils. This is an essential pre-tanning process since it increases the capillary space through which the colloidal tannins can diffuse and makes the polar groups of the protein accessible to the tan. Collagen carries postively and negatively charged polar groups, and collagen fibres contain both bound and free water. Tanning consists in conferring chemical and physical stability on the collagen fibre by the suppression of the active groups and the elimination of water.

Prof. Dr. K. Freudenberg.—*Tannins and their behaviour towards proteins.*

It is known that phenols form molecular compounds with amines and amides (e.g. phenol itself with aniline or urea). The amines and amides can be simple or complex, like proteins ; the phenols also can be simple or complex, as for example the tannins of the gallotannin or catechin groups (whose constitutions are discussed). It is therefore affirmed that, when a tannin and a protein particle come together, a molecular compound is formed first. In a single tannin particle there are available many phenolic groups capable of combining with the active groups of a protein particle. After the first contact the two particles combine in such a way that the greatest possible number of the phenolic and peptide groups are near one another.

The first process is a contact at single points, the second is the mutual permeation of the parts. Until then the process is mainly reversible. The third process is the condensation of the neighbouring tannin particles to insoluble high molecular compounds. The two first steps may be

compared with the adsorption of indigo-white on the fibre ; the third resembles in some way the production of the insoluble indigo itself on the fibre, and this process is irreversible. The third step, that is the self-condensation of the tannin, is portrayed in this connection.

Dr. P. Maitland.—*The chemistry of Quebracho tannin.*

The hypothetical stem substance of Quebracho tannin, the so-called Quebracho-catechin, whose formula was suggested by Freudenberg in 1925, has now been prepared synthetically from the corresponding pyrylium salt. This new catechin is very similar to ordinary catechin itself, and has been condensed to a product which shows many similarities to the purified Quebracho tannin of natural origin.

The ‘ phlobaphene ’ reaction of the catechins has also been studied, and some light thrown on its probable mechanism.

Prof. Dr. M. Bergmann.—*The chemistry of skin, and the catechol tannins.*

Skin is altered by tanning in such a way that it becomes more resistant to putrefaction. The chemical groups of the skin are also so altered by tanning that they can better resist the chemical attack of the proteolytic enzymes of the organisms of putrefaction. This resistance to enzymes is, however, only limited in vegetable-tanned leather. According to the tanning material used, the pre-tanning treatment of the skin and the manner of tanning, the leather can be digested by the proteolytic enzymes to a greater or less extent. The measure of this digestion is a measure of the quality of the tanning. There appears to have been found here a new analytical means for the investigation of leather since progress of tanning can be measured by a falling away of a particular chemical characteristic. By simple experiment it can be shown that liming and bating with enzymes have a quite recognisable influence on the colloidal condition of the skin which must make itself felt during the course of tanning.

The behaviour of a tannin during the tanning process depends directly on its general chemical character. By sulphiting, the chemical nature is altered and it then produces leather of different properties from non-sulphited tans. Even the molecular size of the tannin is of fundamental importance in the tanning process.

These particular lines of thought and experimental methods show the way to a rational method of leather manufacture. The properties of the leather can be altered at will by selected variations of the methods of tanning.

Dr. H. Phillips.—*The nature of the vegetable tanning process.*

Gelatin in solution combines instantaneously with tannins, hide powder less rapidly, whilst the structurally intact hide tans slowly. The speed of tannage is thus governed by the rate of diffusion of the tannins into the hide. This rate of diffusion is dependent on the following inter-related factors : (*a*) the size of the intermolecular spaces in the hide ; (*b*) the intensity of the electrical charge on the protein molecules ; (*c*) the size of the tannin molecules ; (*d*) the charge on the tannin molecules ; (*e*) the degree to which the tannin molecules are hydrated. The non-tannins in vegetable tanning materials play an important part in the process since they influence the size of the intermolecular spaces in the hide and also modify the properties of the tannins. Vegetable tanning materials vary in character, and the tanner blends and manipulates the tan liquors so that penetration of the hide by

small non-tan molecules is followed by the absorption of tannins possessing large molecules. Reasons are given for upholding the view that the combination of collagen with tannins is mainly electrostatic in character, being partly salt formation between tannin and protein and partly association arising from the polar character of the molecules.

Mr. F. C. Thompson.—*The gelatin-tannin reaction.*

This interesting reaction has a long history beginning with Seguin and Humphrey Davy, but has not yet been completely elucidated in spite of the efforts of many workers. The variability in the composition of the precipitate under differing experimental conditions attracted the attention of the earliest investigators and led ultimately to the somewhat vague characterisation of the reaction as a ' colloidal ' or ' adsorption ' reaction. Attempts to gain a closer insight into the mechanism have been made in several quarters. J. T. Wood showed that the reaction had little in common with what is usually considered to be adsorption. Stiasny has emphasised the importance of the degree of dispersion of the reactants, whilst Kruyt has considered the reaction as an electrical discharge followed by dehydration. A simple chemical theory assuming the formation of an insoluble salt from the tannin as acid and the gelatin as base (a salt which largely resists hydrolysis by reason of its high degree of insolubility) is fairly satisfactory up to a point but does not cover all the facts of the case. An adequate chemical theory will probably have to take account, following Freudenberg, of the molecular compounds formed by phenols and organic bases.

Dr. F. E. Humphreys.—*Factors influencing the tanning properties of tan liquors and extracts.*

The average molecular weight and degree of hydration of the constituents of the more common vegetable tanning materials and extracts have been determined. The influence of these factors on the tanning properties of the materials examined is discussed.

Afternoon.

Excursion to Fort Dunlop.

SECTION C.—GEOLOGY.

Friday, September 1—Wednesday, September 6.

Geological Excursion to Shropshire and the Welsh Borderland.

This excursion, carried out under the general direction of Prof. W. W. Watts, F.R.S., occupied the time from September 1 till the opening of the meeting. The headquarters were at Much Wenlock, and the districts visited included the following : the Wrekin, Charlton, and Overley areas under the guidance of Dr. R. W. Pocock ; the Cambrian and Longmyndian Rocks of Caer Caradoc and Church Stretton under the guidance of

Dr. E. S. Cobbold ; the Tremadoc Rocks of Shineton and the Ordovician Rocks of Evenwood with Dr. C. J. Stubblefield ; the Silurian Rocks of Wenlock, Ludlow, Leintwardine, and Onibury with Mr. Shirley and Dr. Whittard ; and the Ordovician and Valentian Rocks of the Onny and the northern Shelve country under the guidance of Dr. W. F. Whittard. The excellent weather allowed of the carrying out of a very full programme, and satisfactory collections of rocks and fossils were made.

Dr. E. S. Cobbold.—*Notes on Comley Quarry, near Church Stretton, Shropshire.*

The geological history of this quarry may be sketched as follows :

In 1878 Dr. Charles Callaway claimed the discovery of Cambrian (' Ffestiniog Beds ') here, on the evidence of brachiopods.

In 1888 Prof. Charles Lapworth announced that he had collected fragments of *Olenellus*, now relegated to the genus *Callavia*, and that the rocks were of Lower Cambrian age.

In 1891 the same author described and figured a number of fragments of *Olenellus* (*Holmia*) *callavei*, as he named the species, together with a restoration of the trilobite so far as was then possible. At the same time he gave a preliminary description of a *Paradoxides* found by T. T. Groom (*P. groomi* Lapw.), which showed that the Middle and Lower Cambrian were in juxtaposition at this spot.

In 1892 Mr. John Rhodes (senior) made a considerable collection for H.M. Geological Survey, under Prof. Lapworth's direction.

Since that time many geologists have visited the area and numerous fragments have been collected.

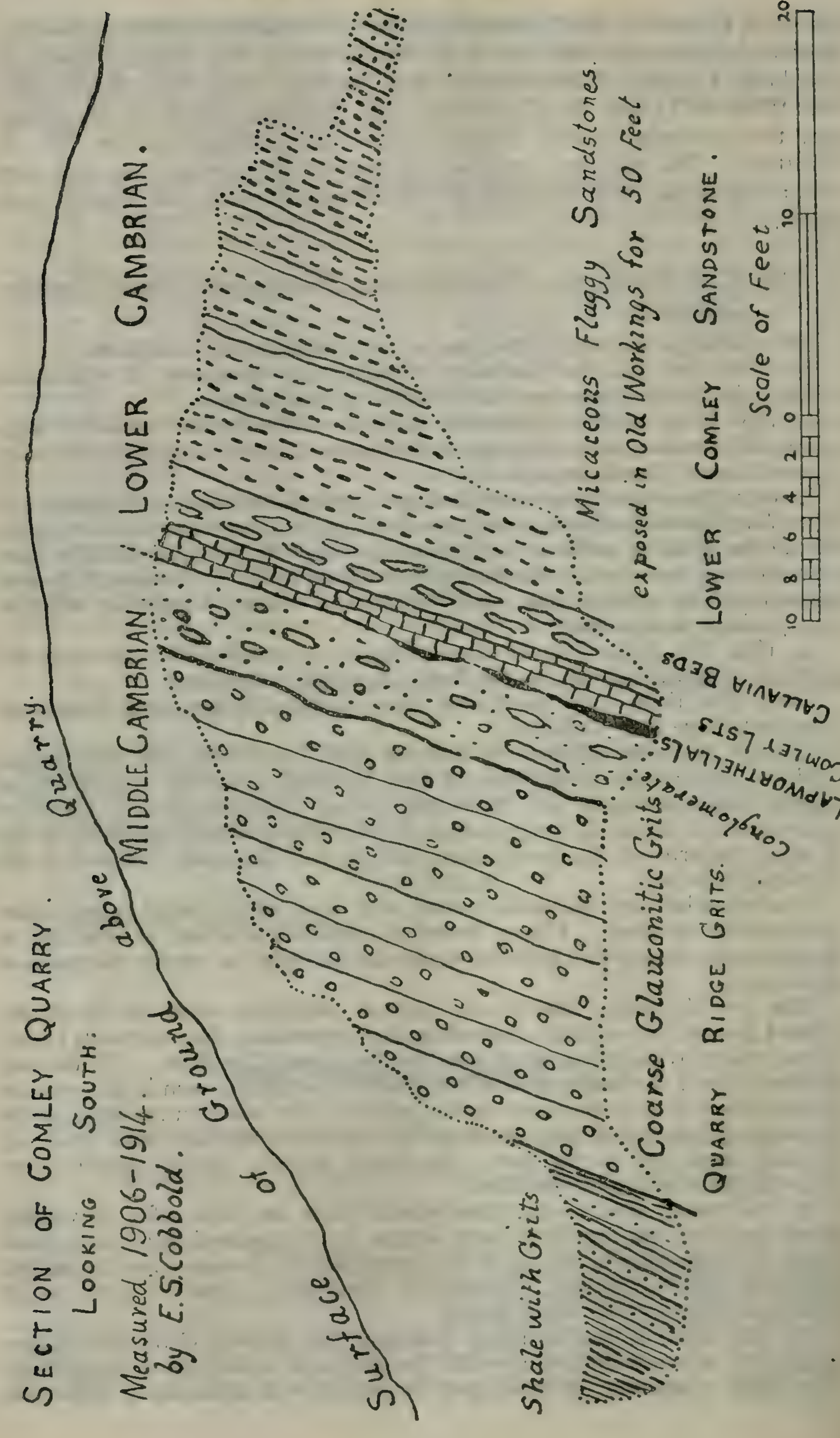
In 1907, with the advice and help of Prof. Lapworth, and with grants made to me by the Committee of the Association for the excavation of critical sections among the Palæozoic rocks, I commenced a series of excavations in the area, the principal results of which have appeared in the Annual Reports of the Association and in the *Quarterly Journal of the Geological Society*.

Quarrying has now been abandoned, and much of the detail is lost under débris and vegetation. I have, therefore, sketched a section of what was to be seen some twenty-five to thirty years ago, in order to supply the present deficiency.

The two divisions, Middle and Lower Cambrian, meet at the darkly shaded line on the section representing the impersistent Lapworthella Limestone, which by its fauna is relegated to the Lower Cambrian. To the east of this we have the coarse grits of the Middle Cambrian, seen in the remains of the quarry face in the south corner and in a depression in the floor, at the eastern end of which they graduate by interpolation into fine shale, all dipping about 70° to the east. An initial deposit, varying greatly from place to place, occurs at the base.

In the trench seen to-day this deposit takes the form of a very dark, gritty breccia ; two or three yards farther on it appeared as a black phosphatic skin adhering to the top of the Lapworthella Limestone, and contained *Dorypyge lakei* Cobbold, *Paradoxides* fragments, now referred to *P. œlandicus* Sjögren, and other fossils.

To the west of the dividing limestone the Lower Cambrian is seen apparently in close conformity with the grits and shales above mentioned. The beds consist of (i) three grey limestones—in descending order the

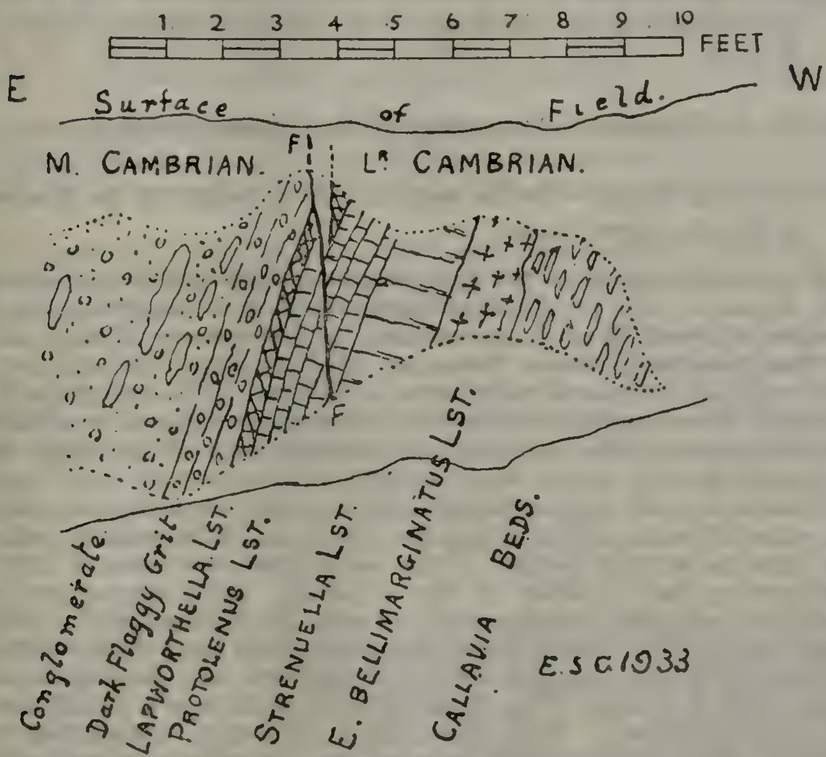

SECTION OF COMLEY QUARRY.
LOOKING SOUTH.
Measured 1906-1914.
by E.S.Cobbold.
Surface of Ground above Quarry.
MIDDLE CAMBRIAN.
LOWER CAMBRIAN.
Shale with Grits
Coarse Glauconitic Grits
QUARRY RIDGE GRITS.
Conglomerate
LAPWORTHELLA LS.
COMLEY LSTS
CALLAVIA BEDS
Micaceous Flaggy Sandstones
exposed in Old Workings for 50 Feet
LOWER COMLEY SANDSTONE.
Scale of Feet
10 8 6 4 2 0 10 20

Protolenus-, Strenuella-, and Eodiscus bellimarginatus-Limestones. Unfortunately, they are much disturbed by strike faults or differential sliding, but are well seen in an excavation 200 yards to the south. Below these come (ii) the Callavia Beds, as we now call the Olenellus Limestone of Lapworth, which graduate downward into the Lower Comley Sandstone.

The five calcareous beds carry very distinct faunas and are regarded as representing five separate faunal horizons.

The Lower Comley Sandstone is seen on the west. It is a green, felspathic and micaceous rock estimated at 450 feet and includes some bands of shale. It is not, as previously supposed, unfossiliferous. The base of this sandstone formation merges, by interpolation, into the Wrekin Quartzite.

SECTION OF COMLEY LIMESTONES AT EXCAVATION N°2



The evidence for the inter-Cambrian unconformity is indicated in this quarry, (1) by the abrupt change in the lithology from fine-grained felspathic sandstones to coarse quartzose grits, (2) by the complete change in the faunas, (3) by the finding of fossiliferous fragments of the pre-existing Lower Cambrian rocks in the conglomerate at the base of the coarse grits.

Further afield in Robin's Tump these same grits are seen to rest with discordant strike and dip upon sandstone beds that are estimated to be 100 feet below the Lapworthella Limestone.

A more striking exhibition of the unconformity is seen within 200 yards of this quarry in the 'Comley Breccia Bed,' where the matrix carries a younger Middle Cambrian fauna (the *P. tessini* fauna of Scandinavia), while the included blocks consist almost entirely of Lower Cambrian Limestones and Sandstones.

The characteristic *Lapworthella nigra* of the Lapworthella Limestone was

so named because it marks the dividing line between the Middle and Lower Cambrian in which Prof. Lapworth was greatly interested. The deposit is black, phosphatic, and calcareous, about 3 inches thick at its best, and crowded with brachiopods (*Acrothyra*) and *Hyolithellus micans*. The little *Lapworthella* shells are abundant. There are also three or more other organisms and some nodular bodies, probably algal in origin.

This limestone occurs in the same stratigraphical position at Rushton.

Transactions at the Leicester Meeting.

Thursday, September 7.

Presidential Address by Prof. W. G. Fearnsides, F.R.S., on *A correlation of structures in the Coalfields of the Midland Province* (10.0). (See p. 57.)

Mr. H. H. Gregory.—*The geology of the Leicester district* (11.0).

Mr. Francis Jones.—*Further notes on the petrology of the igneous rocks of Leicestershire* (12.30).

The intrusive rocks of the Leicestershire-Warwickshire area group into five divisions, viz. (1) Diorite-Granophyres of Charnwood, (2) Micro-diorites of South-West Leicestershire, (3) Mountsorrel Granite complex, (4) Camptonite-Diorites of Nuneaton, (5) Intrusions into Caldecote series. Chronological or genetic correlation is difficult. The age of the last two groups is known within limits: that of the granophyres is established with the fifth group. The 'camptonites' contrast with all the others not only as regards basicity, but in being concordant intrusions of 'wet' magma.

Structural study of the Mountsorrel complex confirms the evidence of its mineral freshness that it is a late intrusion. The isolated outcrops of the non-granophyric diorites of the south-west make special difficulty in interpreting their position in the sequence. Joint phenomena suggest structures excluding contemporaneity with the granophyres. Mineralogically they 'fit in' between the granophyres and the granite. They show diversity of detail mainly in regard to hydrothermal alteration and to the occurrence of epidote. The Croft-Huncote rock is of especial interest in regard to the former. Here albitisation is advanced: analcite and laumontite have been developed as vein minerals, and prehnite occurs within the altered rock. The phenomena developed resemble those described by Gilluly in his paper 'Replacement Origin of the Albite Granite, Sparta, Oregon' (*U.S. Geol. Sur. Prof. Paper*, 175-C).

Afternoon.

Excursion 1: Demonstration of geophysical methods in the field. Leaders: Dr. A. F. Hallimond, Mr. A. T. J. Dollar.

Excursion 2: The glacial geology of the Leicester district. Leaders: Mr. W. Keay and Mr. Martin Gimson.

Friday, September 8.

DISCUSSION on *St. George's Land and the shore-lines of the Midland Barrier during Carboniferous times* (10.0) :—

Prof. W. S. BOULTON.

Name proposed by Jukes-Browne for the continuous tract of land in early Devonian time extending from Wales across St. George's Channel to eastern and central Ireland. Prolonged erosion of this part of the Caledonian continent was followed by submergence ushering in the Carboniferous. The delimitation of St. George's Land during this period is the main subject under discussion.

Repeated oscillatory movements during the Carboniferous and Permian shifted the shore-line, so that it is necessary to refer the land margin at any place to the particular time-division when it so stood. The 'Mercian Highlands' of Midland geologists are the eastern extension of St. George's Land.

A map is exhibited showing the shore-lines in early Tournasian and late Viséan times, and also the areas where Millstone Grit (*sensu stricto*) and Coal Measures were presumably not deposited. The points specially referred to are :

(1) The advance of the shore-line northward followed by retreat southward in the South-West Province during the Avonian, and the southward advance in the Midland Province during the Viséan.

(2) The land boundaries in the Leicester area deduced from outcrop and borehole evidence. A possible sea connection west of Leicester between the Midland and South-West Provinces in Viséan time.

(3) Evidence from the pebbles and breccia-fragments of Permian (Enville) beds points to eroded Avonian under the Triassic cover of the Midlands.

(4) A brief summary of evidence from borings as to the extent of concealed Coal Measures between the Birmingham and Leicester areas.

Mr. E. E. L. DIXON.

St. George's Land appeared in Caledonian times, and during the deposition of the Upper Old Red Sandstone (Farlovian), its southern slopes extended at least as far north as Brown Clee. Subsequent changes on its northern side differed from those on the southern, and resulted in a southern shift of the barrier, the northern side being progressively submerged, whereas to the south land gained on the sea. The changes were due largely to contemporaneous earth movements, but the retreat of the sea on the south was helped by the deposition of grits on the margin—the Cornbrook and Drybrook Sandstones of Titterstone Clee and the Forest of Dean respectively. The barrier was greatly enlarged by the mid-Carboniferous upheaval. On the northern side the later depression which brought about the deposition of the true Millstone Grit (Namurian) and Coal Measures commenced much earlier in the more central parts (N. Staffs., etc.) of the Midland basin than near the barrier (S. Staffs., etc.). The contrast in this respect between neighbouring coalfields is so great as to suggest that the depression included contemporaneous northward down-faulting between the contrasting coalfields. The southward encroachment of the Midland Province was only checked by the mid-Carboniferous upheaval, and when sedimentation was resumed it extended over what had formerly been part of the South-Western

Province. Thus Titterstone Clee, formerly part of the latter, was covered with Coal Measures of Midland facies.

Dr. T. Neville George.—*The Carboniferous shore-line in S. Wales.*

The general Armoricanoid trend of the South-Western Province was established in pre-Carboniferous times, and the Carboniferous sediments accumulated in an oscillating geosyncline to the south of St. George's Land.

Though generally the Lower Limestone Shales are conformable with the underlying O.R.S., they locally transgress, and probably overlap northwards. Thus the shore-line at the commencement of the Carboniferous can be fixed, and its movements in Lower Avonian times deduced.

The intra-Avonian unconformity, visible between the Vale of Neath and Kidwelly, indicates a southward retreat of the shore-line in C_2S_1 times, followed by a re-advance, causing S_2 beds to transgress probably down to the O.R.S.

In D times the shore-line lay beyond the existing coalfield, though not far distant to the north. At the close of the Avonian, regional emergence accounts for the unconformity beneath the Millstone Grit; while the overlap of higher goniatite zones over lower ones suggests an embayment in the mid-portion of the North Crop between two southward-extending headlands.

The east to west trend of the Armoricanoid axes was modified in places by transverse structures which had considerable effect upon sedimentation and coast-line configuration during the Carboniferous period.

Dr. E. Neaverson.

The Carboniferous Limestone of Flintshire and Denbighshire forms a fringe dipping off various zones of Lower Ludlow rocks which formed the Carboniferous land surface in this part of St. George's Land. West of the Denbighshire Moors the great Ordovician tract of Snowdonia extends north into Anglesey. Carboniferous rocks occur in the eastern part of this island and on the southern shore of the Menai Strait. The ancient shore-line in North Wales is now modified by marginal faulting of comparatively slight effect as a whole.

The limestone often rests on a basement of red conglomerate and sandstone containing water-worn boulders of older rocks. In Anglesey these are mainly pre-Cambrian and Ordovician rocks of local origin. Around the Denbighshire Moors the red beds contain abundant boulders of Upper Ludlow flagstone not known *in situ* in North Wales, but a former northward extension from the type-area is indicated. The junction of basement beds and limestone corresponds approximately with the base of the Dibunophyllum zone, thus dating the Carboniferous transgression from the north.

The Carboniferous Limestone is formed almost entirely of marine organic debris; hence peneplanation of the adjacent land mass is inferred, or perhaps a cliffed plateau protected against marine abrasion by offshore shoaling.

In the Vale of Clwyd the lithology of the D_1 limestones suggests a landlocked bay with slight tidal range. There is some evidence of overlap at the southern end of the Vale, though nothing higher than D_1 occurs on the western side. The present Clwyd Range was possibly separated from the western massif in D_2 times, and there was probably an extension up the Dee Valley to Corwen in D_3 times. The occurrence of knoll-limestones in North Flintshire is noteworthy.

In Flintshire the Holywell Shales have yielded marine faunas representing several goniatite zones. Above these are typical Coal Measures which

connect with the Midland Coalfields. In the Vale of Clwyd the limestone is overlaid by the Purple Sandstone, usually ascribed to the Lower Coal Measures. Coal Measures of limited extent are known under the Drift in Anglesey.

Carboniferous rocks were probably never deposited on Snowdonia, the Denbighshire Moors and the Clwydian Hills. The western extension of St. George's Land across the Channel to Ireland is questionable.

Mr. T. Eastwood.

South Staffordshire furnishes examples of proximity to land during Upper Carboniferous times—the ' Silurian banks,' extending as north-to-south peninsulas or islands to the north of St. George's Land. These banks were completely submerged before the Upper Coal Measures were deposited, though land still occurred to the south as is evidenced by the overstep of the Halesowen Group and by other facts.

In Warwickshire there was land, probably an island, north of Nuneaton. South of Nuneaton basal Coal Measure Shales rest upon Cambrian Shales indicating deposition in quiet waters some distance from a shore-line. Later, at Dosthill, an island of Cambrian Shales contributed breccia to the Etruria Marls, while in the same locality the Productive Measures show few signs of proximity to land. The Cambrian Shales also contributed material to the Etruria Marls at Nuneaton ; but farther south the latter formation is barely distinguishable from Productive Measures, and this suggests a northerly provenance, though land probably lay some distance to the south and furnished material for the Corley conglomerates.

Between the Warwickshire and Leicestershire Coalfields the Trias rests on older rocks probably folded along meridional axes of pre-Triassic date. In borings at Chilcote and Desford rocks were encountered which may be interpreted as shore-line deposits.

Dr. W. R. Jones.—*Silicosis : the minerals which cause it* (12.15).

The definition accepted at the International Congress on Silicosis at Johannesburg, in 1930, was, ' Silicosis is a pathological condition of the lung due to inhalation of silica dioxide,' and that ' to produce the pathological condition, silica must reach the lungs in a chemically uncombined condition.' Also, under English law (Silicosis Scheme for compensation), free silica is the basis : ' For the purposes of this Scheme (No. 342 of 1931) silica rock means quartz, quartzite, sandstone, gritstone or chert, but does not include natural sand or rotten rock.'

Cases in the anthracite district of South Wales came under the direct notice of the author, however, where no rock of the type named in the Scheme occurred in the underground working-places of the deceased, although post-mortem examination confirmed silicosis as the cause of death. It was therefore decided to investigate the possibility that rocks other than those included in the Scheme caused silicosis. This was done by examining the mineral residues from twenty-nine lungs, each from a person whose death had been certified as due to silicosis or to silico-tuberculosis. The cases include potters, colliery workers, a stone-mason, and a silica-brick worker. Residues from other lungs have also been examined (fifty-one in all) ; they include pulmonary cases other than silicosis, and a normal lung used as control.

The bulk of the mineral residues obtained from each of the silicotic lungs consists of minute fibres of sericite. This mineral is abundantly present also in all the rocks which gave rise to the inhaled dust ; it is present in these

in the size and form in which it is found in the residues and in sections of silicotic lung tissue. Silica in the uncombined state (quartz) is also present in these residues as relatively coarse and fine grains; it occurs, however, in amounts subordinate to sericite. Especially is this so with regard to the small number of quartz particles as compared with the countless fibres of sericite. One of the largest of these grains of quartz contributes as much silica, in a chemical analysis of a residue, as 1,630 fibres of sericite of the size found in the residue and in the lung tissue.

Silica in the uncombined state is not the chief cause of silicosis. This appears to be established by: (*a*) the examination of the mineral residues and sections of silicotic lung tissue under the petrological microscope; (*b*) the chemical analyses of these residues; (*c*) the numerous cases of silicosis where rocks containing sericite are worked (*e.g.* South Wales Coalfield, the Rand, South Africa), and the complete absence of silicosis where silica rocks containing as much free silica (Scottish Coalfields) and even a higher percentage (Kolar Coalfields, India) have been exploited by thousands of underground workmen for a long period of years; (*d*) many cases of silicosis in mines where the ore and adjacent rocks contain only a low percentage of free silica; and (*e*) by the fact that no silica rock hitherto investigated has given rise to silicosis-producing dust except those which contain sericite or fibrous minerals.

It is submitted, therefore, that it is mainly the presence in the exploited rocks of fibrous minerals, be they sericite, sillimanite, tremolite, etc. (or a fibrous form of free silica as in chert, or a fibrous rock as in pumice), in aggregates which become freed into the atmosphere as individual fibres, that enables sufficient material in course of time to enter the lungs to cause silicosis.

AFTERNOON.

Excursion to the Carboniferous Limestone inliers of the Breedon district. Leader: Prof. H. H. SWINNERTON.

Saturday, September 9.

Excursion to the Pre-Cambrian and Cambrian of the Nuneaton district. Leaders: Prof. L. J. WILLS, Dr. F. RAW, Mr. F. W. SHOTTON.

Sunday, September 10.

Excursion to the Pre-Cambrian of the Charnwood Forest area. Leaders: Prof. W. W. WATTS, F.R.S., Mr. H. H. GREGORY.

Monday, September 11.

Dr. A. RAISTRICK.—*The microspores of coal and their use in correlation* (10.0).

The microspore-content of coal samples can be extracted and isolated by the use of solvents such as Schultz solution, followed by ammonia, which remove the oxidisable coal matrix and leave the spore exines and microspores untouched. The microspores are mounted for micro-examination, and are dealt with statistically, in the same way as tree pollen in peat investigations. Microspore types are very varied and very definite, and their determination in the micro-separations is a matter of precision. There is

good evidence that particular coal seams are characterised, over a wide area, by an assemblage of certain groups of microspores present in fairly definite proportions. The principal microspore types are illustrated and described.

Prof. G. HICKLING and Mr. C. E. MARSHALL.—*Recent studies of plant structure in coal* (10.35).

Improvements in the technique of section-cutting and photography have made it possible to show that coal consists largely of plant-remains in which the details of the original structure are preserved with remarkable perfection. This detail, in some respects, far exceeds that which can be observed in the familiar calcified or silicified petrifactions or coal-balls, since in the coal most of the original substance of the plant remains, while in the petrifaction it has been replaced. By the study of isolated sheets of bark and portions of wood which are preserved as coal in the coal-measure shales the microstructure of the plants can be studied in relation to their external form. The bark-structures of *Lepidodendron*, *Bothrodendron* and *Sigillaria* have been so studied, as well as certain woods. In certain cases it appears possible to demonstrate conclusively that the existing coal consists in part of the original plant-substance and in part of additional organic material which has been absorbed by the plant after death.

Mr. A. T. J. DOLLAR.—*The dike-swarm of Lundy* (11.30).

The Lundy dike-swarm comprises 122 dominantly vertical rock-sheets of basic and intermediate composition which occur respectively in the proportion of 91 : 9. It includes typical crinanites, olivine- and analcite-dolerites, quartz-dolerites and tholeiites, together with orthophyres, vitreous and non-vitreous andesites and pitchstones. Extreme types are represented by metallic ores, gabbroid rocks and very vitreous pitchstones. The assemblage as a whole is distinctly Tertiary in affinity.

These dikes cut both the coarse granites and Devonian sediments of the island with an average frequency of 26 per linear mile of coast. The mean thickness of an individual sheet is about 4 ft., but the basic varieties range between ½ in. and over 20 ft., while the less abundant types of intermediate composition generally exceed 10 ft. in breadth. The width of the swarm is approximately coincident with the north-south length of the island, and a crustal extension of 3 per cent. has been produced in this direction by the minor injections.

Apart from intermediate and basic intrusions there are numerous thick and thin inclined sheets of microgranite which are confined to the major granites of the island, while many quartz veins cut both the granites and sediments. The two kinds of microgranites are remarkable for their similarity to granophyric rocks of the Mourne Mountains, Ireland.

The distribution of intermediate and basic dikes is rigidly controlled by jointing and fan-fractures. The latter radiate from centres which appear to lie on submarine planes of weakness. Magnetic properties of the basic dikes have been investigated and are comparable with those of corresponding British Tertiary rocks.

Dr. FREDERICK WALKER.—*The Crinanite dike of Maiden Island, Oban* (11.45).

The bulk of Maiden Island (about 1½ miles north-north-west of Oban) consists of a north-north-west crinanite dike of great breadth and considerable diversity of composition. The west contact of the dike is not

visible, but the eastern one shows a junction with a quartzite conglomerate. The length of the visible portion of the dike is just under 400 yards, while the greatest breadth is 125 yards. The crinanite occurs as medium-grained and very coarse varieties which have sharp, unchilled junctions, and segregation veins are abundant. These veins include felspathic, zeolitic, and picritic types. The last type occurs as a contemporaneous marginal modification, and thus affords an interesting problem in differentiation. The mutual relations of the various modifications are discussed in this paper.

AFTERNOON.

Excursion to Corby ironstone district. Leaders: Prof. W. G. FEARNSIDES, F.R.S., Dr. A. F. HALLIMOND.

Tuesday, September 12.

DISCUSSION on *The origin of red sedimentary rocks* (10.0):—

Prof. G. HICKLING.

There has long been almost universal agreement that 'red rocks' are of non-marine origin ; but the exact conditions under which they have been formed are still open to discussion. They show two marked facies : unstratified sandstones, and red marls of peculiar composition which often contain saline deposits. Normal limestones are absent, but magnesian limestones may be developed. Breccias and conglomerates of several unusual types are commonly found. Fossils are rare and occur sporadically in very restricted areas. Except in the occasional magnesian limestones, which may yield stunted marine forms, the fossils are restricted to fishes, land vertebrates and a limited flora. Long duration of stable conditions is indicated by the occurrence of faunas of widely different ages in a sandstone mass without any determinable stratigraphical break between them. The red coloration is attributable to prolonged exposure of the sediments above the ground-water level, though they may have been subsequently distributed and deposited by water. It is aided by the total absence of carbonaceous colouring matter which results from a restricted flora and the complete oxidation of any organic remains. Red rocks may show a lateral passage to a marine facies, usually with an intermediate zone of alternating conditions. It is suggested that the rocks are the product of arid or semi-arid delta or flood-plain conditions, and that the explanation of the different types of deposit is to be sought mainly in variations of humidity and temperature, coupled with the effect of earth-movement in bringing the surface of deposition above or below the level of the ground-water.

Prof. W. S. BOULTON.

Arising from his studies of the Red Rocks of the Midlands, the speaker refers to breccia- and conglomerate-formation in relation to contemporaneous earth movement. Attention is drawn to peculiarities of recurrent coloration in sands, and to peculiarities in *Spirorbis* limestones.

Prof. W. T. GORDON.

The evidence of the plants as to the physical and climatic conditions during the formation of the red beds.

Mr. F. W. Shotton.

Examination of the cores of a group of three boreholes near Coventry led to the discovery of a typical 'Permian' breccia band in the middle of the Allesley Conglomerate Division, well below the first appearance of breccias previously known in the Warwickshire coalfield. A detailed study of the constituents of all the pebbly horizons in the boreholes provided some data which has a bearing upon the mode of deposition of breccias and conglomerates during the formation of the Midland Hercynian ranges.

In the first place, the small quantity of pre-Cambrian material in the conglomerates is always angular, while any Silurian or Avonian fragments in the breccia are well rounded. Hence it is concluded that the production of a breccia or of a conglomerate depended mainly on the nature of the rocks that were undergoing erosion.

Secondly, there is a deposition-cycle from conglomerates (mainly of Avonian pebbles) to a breccia of pre-Cambrian material and back to a conglomerate. Now since it is likely that the cores of the Hercynian ridges would be mainly pre-Cambrian rocks, a general uplift with increased velocity of the rivers would lead to the distribution of pre-Cambrian pebbles in the intermont basins where previously only the more local Avonian and Silurian material had been transported. From this it is deduced that the observed cycle of deposition coincides with a period of uplift of the adjacent mountains, followed by their gradual lowering by erosion.

Dr. Bernard Smith, F.R.S.

In general red rocks contain less iron than non-red rocks. The colour is due to dehydration of ferric oxide, which takes place most rapidly in warm, moist climates under conditions usually productive of heavy vegetation. Residual soils of such regions may be distributed by streams without losing their ferric oxide. If subjected to powerful reducing action in swamps or the sea they usually lose their red colour.

A residual soil underlies part of the Carboniferous Limestone of West Cumberland, and in the Carboniferous Basement Beds of part of North Wales red beds derived from residual soils give place upwards to marine lagoon-phase deposits.

Most of our red beds were doubtless formed under desert or semi-arid conditions ; yet the question arises whether certain sediments laid down in comparatively arid tracts were not derived from uplands with residual soils formed under warm, moist conditions. We may, indeed, have to reconsider some of our views.

In normal Coal Measure times the hinterlands may have supported a considerable upland flora and a red residual soil. There would be oxidation of this vegetation *in situ*, and reduction of the ferric oxide of the soil swept into the swamps.

In Upper Coal Measure times, when coal swamps were at a minimum, relative uplift of the land (of which there is internal evidence) probably brought about a freer drainage, entailing less chance of reduction of ferric oxide to the ferrous state.

True aridity, however, seems to have set in towards the end of the period.

Dr. H. C. Versey.

In the Penrith Sandstone two periods of coloration are found : i.e. pre-cementation and post cementation. Part of the iron oxide is, apparently, precipitated from colloid solution, but much is detrital. The impossibility

of marked climatic difference between the highland source area and the area of deposition leads to the conclusion that the red coloration is only in part due to dehydration in the arid Permian climate, but mostly to detrital iron oxide formed in the monsoonal conditions of the Upper Carboniferous.

Prof. D. M. S. WATSON, F.R.S.

The speaker reviews the evidence afforded by the contemporaneous fauna as to the conditions in which the red beds were formed.

Mr. J. H. TAYLOR.—*Contribution to the petrology of the Mountsorrel igneous complex* (12.0).

The paper deals with two aspects of the complex which have received little attention : (1) the nature and characteristics of the accessory minerals ; and (2) the processes by which the several members of the complex were formed and emplaced.

Under (1) some twenty mineral species are recorded from the area and described in detail, particular attention being given to the widespread and varied zircon and apatite. Points of special significance are the corrosion of many of the zircons, and the occurrence of dark, sometimes almost black, apatites.

Under (2) the view is expressed that both granodiorite and quartz-mica diorite are of hybrid origin, resulting from the action of acid magma on basic rock. The latter was almost certainly the gabbro of Swithland reservoir, while some indication of the nature of the acid magma is afforded by a thin marginal facies of the granodiorite that has the composition of alkali granite. The granodiorite was formed below present ground level, and was subsequently injected into the position it now occupies.

Three new chemical analyses are quoted and discussed, and comparisons are made with rocks of the Channel Islands, Dartmoor and the Isle of Man.

Dr. F. RAW.—*On the Triassic and Pleistocene surfaces developed on some Leicestershire igneous rocks* (12.15).

The well-known grooved and polished surfaces exhibited by some of the Leicestershire igneous rocks have long been regarded as dating from the Triassic period, and as bearing evidence of formation by natural sand-blasting under desert conditions. The author has reached the conclusion that these features are here due to the Pleistocene glaciation.

AFTERNOON.

Excursion to the granite area of Mountsorrel. Leaders : Mr. H. H. GREGORY, Dr. E. E. LOWE.

Wednesday, September 13.

Dr. L. S. B. LEAKEY.—*The age of part of the Rift Valley in Kenya* (10.0).

In East Africa, work during the past seven years has thrown much new light upon the age of the Great Rift Valley, which was formerly considered to be an event of Mio-Pliocene age, with only small secondary movements during the Pleistocene.

On the new evidence it would appear that the greatest period of faulting, when faults of a throw of over 1,000 ft. took place, occurred during the latter part of the Pleistocene, long after man was in the country.

The evidence is discussed and compared with similar evidence from the other parts of the Great Rift Valley, both north and south of East Africa.

Dr. S. W. WOOLDRIDGE and Mr. J. F. KIRKALDY.—*The longitudinal profiles of certain rivers in southern England, and their bearing on the eustatic theory* (10.40).

A comparison is instituted between the longitudinal profiles of the Kentish Stour, the Mole, the Rother (East Sussex), the Rother-Arun, the streams of the Hampshire basin and some of the East Anglian rivers.

In all cases the curves are composite, indicating successive phases of rejuvenation with respect to successive marine base levels. For the area of the Weald and the Hampshire basin the close correspondence of rejuvenation features points to a general absence of differential warping during Pleistocene times—a conclusion also enforced by the attitude of the higher and older erosion surfaces. There seems thus to be good ground for supporting the application of the eustatic theory to the classification of the Pleistocene deposits of the area ; though it has been very generally ignored by British workers on the wholly inadequate grounds that it does not apply to regions like Scandinavia, East Anglia, etc., whose physiographic history is, in fact, entirely different.

The composite character of the curves is also used to invalidate the common assumption that terraces fall on a curve parallel to the present valley bottom. In many cases this is demonstrably not the case, and the consequences in the field of palæontological and archæological correlations are noteworthy.

Mr. H. C. COOKE and Mr. W. A. JOHNSTON.—*Possibilities of increasing the gold production of Canada* (12.10).

The Canadian Shield, from which 92 per cent. of Canada's gold now comes, is likely to yield still larger amounts in the next few years. The three gold-producing provinces of Manitoba, Ontario and Quebec have all shown a rapid increase in annual production during the last seven years, and analysis of the causes of the change indicates that further important increases are to be expected, particularly in Ontario.

Unless new discoveries are made in the near future, lode gold production from British Columbia will probably not increase notably in the next few years, and may even decrease somewhat with exhaustion of the Premier mine, the largest present producer.

Placer gold production from Yukon may increase in the next few years if the number of dredges in use is increased. In British Columbia, hydraulicking is the chief method of placer mining and will continue for many years, but the annual output of gold from this method of mining may not much exceed the present output. More efficient methods of recovery of fine gold, for example by flotation, offers some prospect of success for dredging of bar deposits on streams in British Columbia and Alberta. Extensive prospecting that is being carried on may result in the discovery of new fields.

REPORT OF RESEARCH COMMITTEE on *Critical Sections of Tertiary and Cretaceous rocks* (12.30).

SECTION D.—ZOOLOGY.

Thursday, September 7.

PRESIDENTIAL ADDRESS by Dr. J. GRAY, F.R.S., on *The mechanical view of life* (10.0). (See p. 81.)

Mr. E. HERON-ALLEN, F.R.S.—*Diffusion and extension phenomena observed in the behaviour of living protoplasm* (11.0).

Dr. G. P. BIDDER.—*The energy of flagellate cells* (11.30).

My estimate of the work done per second per gramme weight of sponge flagellate cells (*Brit. Ass. Report*, Leeds, 1927, p. 73) was a modification of calculations explained to the Society of Experimental Biology in 1924, based (*a*) on velocities observed in isolated cells compared with rate of vibration of their flagella; (*b*) on *a priori* calculations from size and rate of vibration of the flagella; (*c*) on the observations of velocity from the vent of *Leuconia* (= *Leucandra*) *aspera*, resistance in its channels, and the number of its collar cells, described to Section D at Hull (*Q.J.M.S.*, 1923, p. 293).

Through Prof. Dohrn's kindness, I made in 1932 new experiments at Naples on the current from the vent of *L. aspera*, afterwards weighing alive in sea-water the sponges used. The improved experiments have made it possible to calculate the oscular velocity from each observation of the further part of the jet; they verify the theoretical conclusion (*Q.J.M.S.*, 1923, p. 320) that the oscular velocity is characteristic of the species, and irrespective of size of individual. With this velocity the determination of the protoplasmic volume gives a solid datum for a more certain estimate of the useful work done per gramme of collar cells—necessarily very small compared with the efficiency of purely motor protoplasm.

Dr. V. B. WIGGLESWORTH.—*The rôle of water in the physiology of excretion in insects* (12.0).

The elimination of waste products, particularly the elimination of nitrogen, with the least possible loss of water is one of the chief problems with which insects, in common with all terrestrial animals, are faced. Insects discard their nitrogen chiefly as uric acid, which can be readily precipitated and excreted in solid form. In the blood-sucking bug, *Rhodnius prolixus*, the precipitation of free uric acid is brought about by the secretion of urate in solution in the upper parts of the Malpighian tubes and the reabsorption of base and of water in the lower parts. In many insects a further mechanism for the recovery of water exists at the hind end of the gut, where the so-called rectal glands, or the general rectal epithelium, reabsorb water from the excrement before it is allowed to leave the body. In the aquatic larva of the mosquito, the so-called anal gills, which bear a superficial resemblance to prolapsed rectal glands, absorb water from the surrounding medium so that a constant supply is available for excretion, and only when this absorption is prevented experimentally does solid uric acid appear in the excretory system.

Dr. GEORGE SALT.—*Experiments on the behaviour of insect parasites* (12.30).

Most animals are capable of increasing their numbers very rapidly, but are prevented from doing so, partly by carnivorous animals that prey upon

them. In this connection the group of insect parasites known as parasitoids (' refined predators ') are very important and have been used in many parts of the world to limit the numbers of noxious organisms. The problems involved in the use of these beneficial insects are obviously problems of population, since they deal with the numerical interaction of the parasites and their hosts ; but they are also problems of animal psychology, since the behaviour of the individual parasites and hosts must be considered.

One of these problems is that of the selection of suitable hosts by the parasite. It has been supposed that parasites are distributed in a given host population at random, and on this assumption a theory of parasite distribution has been developed. But the field observations and the laboratory experiments described show that the basic assumption is not true. Some parasites have the ability to discriminate between suitable hosts and those that have already been parasitised, and they distribute themselves much more efficiently among the host population than chance would do. This result is discussed from the two points of view, of populations and of insect behaviour.

Afternoon.

Dr. G. C. Robson.—*The limitations of adaptability in the animal kingdom* (2.15).

The main phyla and the subordinate groups of the animal kingdom differ markedly in their range of adaptability (i.e. specialisation for a particular mode of life). Differences of this kind are probably to be found in all animal activities, e.g. in the incidence of parasitism, methods of getting food, etc. The author dealt chiefly with the question of habitat-occupation, and pointed out that, whereas several of the main animal groups had been highly successful in colonising a large range of habitats, other equally large groups have a far more limited range. Thus the Insecta have failed to produce more than a few truly marine forms ; the Cephalopods have not established themselves in water below normal marine salinity ; the Echinoderms have not made their way into fresh water, though a few occur in estuaries. The incidence of habitat-occupation in the various families of Gastropods was described and sundry cases of apparently idiosyncratic adaptability were given. The adaptive achievements of certain groups were then contrasted with their limitations, and the failure of the Lamellibranchs to establish themselves on land and of the Cephalopods to colonise either land or water of less than normal marine salinity was discussed. The nature and origin of the factors limiting adaptation were considered. The writer felt that individual predilection could not be excluded from the various factors determining habitat-occupation.

Mr. A. Roebuck.—*The rook in the rural economy of the Midlands* (3.0).

Rooks have been studied in five midland counties—Leicestershire, Derbyshire, Nottinghamshire, Lincolnshire, and Rutland.

A census of the whole area, repeated after an interval of four years, showed the rook population to be constant.

About 10 per cent. of the rookeries change their sites annually.

There is no evidence that migration materially affects the problem in the Midlands.

The distribution of their roosts during the winter is considerably different from that of their nesting rookeries, although many remain on the same sites all the year round.

Except for a brief period rooks are restricted to a limited area for a feeding-ground, the area in the vicinity of the rookery. Those roosting at a distance in winter return daily.

The census gives the rook population when it is at its lowest.

The nesting season is coincident with the emergence of insect life and their rapid reproduction.

During the months of March to July, when the young are reared, the proportion of insect food in the diet is at its highest.

The greater proportion of the annual food is also consumed in this period.

The quality of the food eaten varies somewhat in different localities and is necessarily associated with the type of local husbandry.

Mr. M. A. C. Hinton.—*The musk-rat and its problems* (3.30).

Friday, September 8.

Prof. D. M. S. Watson, F.R.S.—*The origin of land-living vertebrates* (10.0).

Mr. G. L. Purser.—*Some points in the anatomy of Calamoichthys* (11.0).

Mr. J. T. Cunningham.—*Conditions of life and reproduction in Lepidosiren, the South American lung-fish* (11.30).

The eggs and larvæ of Lepidosiren develop in a nest-burrow at the bottom of a tropical swamp. The larvæ are provided with external gills, and the male parent, which is found with its progeny, has long vascular filaments on its pelvic limbs. These filaments are absent or rudimentary in the female, and developed only in the breeding season of the year. It was proved experimentally by Carter and Beadle in 1927–28 that the water at the bottom of the swamp contained little or no dissolved oxygen, and by Cunningham and Reid in 1930–31 that oxygen was emitted by the filaments when the fish bearing them was placed in deoxygenated water. It must be concluded that the respiration, and therefore the life of the eggs and larvæ, depend on the oxygen given off by the filaments of the male parent. This is the first case in which evidence has been obtained of the emission of oxygen to the external medium as the normal function of special organs in any animal.

The evolution of the filaments is discussed in relation to modern theories and concepts, and the theory that the peculiar conditions have acted only by selection, direct or indirect, of mutations not caused by these conditions is rejected.

Miss A. M. Bidder.—*The alimentary canal of the Cephalopoda* (12.0).

The structure of the digestive system in a representative series of Cephalopoda (including *Nautilus pompilius*) was examined, and the results compared with existing descriptions. Where possible, living or fresh material was used. Gut-contents showed a macrophagous carnivorous diet for the whole group.

The digestive tract consists throughout the group of (1) a buccal mass containing beak-like jaws and radula (he last absent in Cirromorpha only) ; (2) œsophagus ; (3) a muscular stomach, or gizzard ; (4) a more thin-walled cæcum ; (5) intestine. Fore-gut glands open into the buccal mass, and mid-gut digestive glands into the cæcum. Œsophagus and stomach are lined with a cuticle, cæcum and intestine with a ciliated mucous

epithelium. It was found that the cæcum has an elaborate structure constant for the group, and contains a ciliary collecting mechanism.

Principal variations are : (1) presence or absence of a ' crop ' ; (2) relative size and form of stomach and cæcum ; (3) length of intestine ; (4) size and form of the glands. True size of an organ is very difficult to determine owing to individuals differing in (*a*) state of feeding ; (*b*) fixation. Discussion follows of function in the various parts, and possible functional significance and mutual relationships of variations in (*a*) internal volume, (*b*) internal surface area of the gut, and (*c*) size and nature of the mid-gut gland.

Mr. P. S. MILNE.—*The distribution of insects by currents at various levels in the atmosphere* (12.30).

Insects which are being carried about by air currents are filtered from the atmosphere by the action of the wind upon a conical collecting net supported above the ground by a system of kites.

The net is sent up closed to the desired height, is allowed to fly open for a predetermined period, and, after closing again, is hauled down for an examination of the catch. The opening and closing of the net are controlled by a simple chemically-operated release mechanism.

By this means a knowledge of the influence of wind upon the distribution of insects is being obtained. Particular attention is being paid to agricultural pests, and their possible introduction into this country from the Continent at high altitudes.

AFTERNOON.

Visit to the Midland Agricultural College, Sutton Bonington.

THE MEMBERS OF THE SCIENTIFIC STAFF OF *Discovery II.*—*The effect of currents on the plankton distribution in the surface waters of the southern oceans* (2.15) :—

Mr. G. E. R. DEACON.—*Hydrology.*

There are three kinds of surface currents in the southern oceans : antarctic surface currents, sub-antarctic currents and sub-tropical currents. These currents are movements of antarctic, sub-antarctic, and sub-tropical waters, and their speeds and directions are directly responsible for the distribution of the three types of surface water. There are generally well-defined convergences on the surface between the different waters, and these divide the southern oceans into antarctic, sub-antarctic, and sub-tropical zones. The waters of the three zones differ in their characteristics and consequently in the type and quantity of life which they can support : the differences are due partly to the origin of the waters and partly to the climatic conditions of the zones in which they are found. The hydrological conditions in each zone are almost uniform and only change gradually with latitude. The greatest differences are found in the antarctic zone, where, south of 65° in the Atlantic and Indian sectors and south of about 68° in the Pacific sector, the surface water flows westwards. North of this current the water flows eastwards. The eastward-flowing antarctic water receives additions from the westward-flowing current, and also mixing of antarctic and sub-antarctic surface waters takes place in a few areas where the antarctic currents are deflected northwards by the configuration of the land or by irregularities in the topography of the sea-bottom. The easterly antarctic

current receives additions from the westerly near South Georgia and near the Kerguelen-Gaussberg ridge ; mixing of antarctic and sub-antarctic water takes place across the Antarctic Convergence between the Falkland Islands and South Georgia.

Mr. DILWYN JOHN.—*Plankton.*

The different surface waters of the southern hemisphere have distinctive planktonic faunas. The recent work of the R.R.S. *Discovery II* has led to an extensive knowledge of those of the antarctic and sub-antarctic surface waters ; series of tow-nettings were made across each kind of water in all sectors of the hemisphere and at all seasons of the year. The boundary which separates them, the Antarctic Convergence, acts as a hard and fast barrier to the horizontal distribution of certain groups of animals though not to others.

Two species of *Euphausia* occur only in the antarctic, four only in the sub-antarctic : there is one species, an exception, which occurs in both. Two *Chaetognaths*, species of different genera, occur very numerously throughout the surface waters of the antarctic and sub-antarctic, but in both species there are two ' races,' one confined to each kind of water. Few *Copepoda* are limited in their horizontal distribution by the Antarctic Convergence. In some places where there is a bend in the convergence and abnormal hydrological conditions occur, areas of mixed antarctic and sub-antarctic plankton are found. The extent to which the power of vertical migration is involved in this horizontal mixing is discussed.

The surface current of antarctic water flowing to the west, south of 65° S., has planktonic forms peculiar to itself. They are carried north, even to the convergence, where the configuration of antarctic land deflects this water northwards. The most interesting and important example is the wide distribution of whale-food, *Euphausia superba*, in the sector of the antarctic which is affected by the Weddell Sea current.

Mr. F. S. RUSSELL.—*The behaviour of marine plankton animals in relation to the conditions of their surroundings and to their life-cycles* (3.15).

Mr. P. ULLYOTT.—*Vertical movements of the Zooplankton* (3.45).

Saturday, September 9.

Excursion to Charnwood Forest. Leader : Mr. W. E. MAYES.

Monday, September 11.

Mr. L. C. BEADLE.—*Osmotic regulation in Gunda ulvæ* (10.0).

Dr. STEWART MACLAGAN.—*The prediction of insect outbreaks in Britain* (10.30).

DISCUSSION on *The structure of protoplasm* (Mr. J. E. HARRIS ; Dr. D. JORDAN LLOYD ; Mr. W. T. ASTBURY) (11.0).

AFTERNOON.

Dr. H. O. BULL.—*The experimental study of conditioned responses in fishes* (2.15).

Dr. C. F. A. PANTIN.—*Nerves and nerve-nets in Invertebrates* (3.0).

Nervous action in the Invertebrates is often said to differ fundamentally from that in the Vertebrates. But in fact there appears to be only one important difference. Except in the Vertebrata, ' peripheral facilitation ' is enormously developed, especially between nerve and muscle. That is, the first nervous impulse passes into few or none of the muscle fibres, while each succeeding impulse is increasingly successful in doing so. This is responsible for the varied muscular responses of the Crustacea, the Actinozoa and probably the Echinoderms. The special properties of the nerve-net in the latter groups are due to facilitation.

The natural responses of the Actinozoa are effected by well-defined muscles, which fall into two groups according to their relation to the nerve-net. In one the net acts as a simple conducting unit from the site of the stimulus to the muscle ; facilitation occurs only between the nerve-net and the muscle. In a second group the nerve-net supplying the muscle is partly isolated from neighbouring regions of the net. Between these regions inter-neural facilitation takes place. This analysis throws much light on the nature of autonomy in the nerve-net and on the origin of polar conduction. A fairly complete picture can be drawn of the Actinian nerve-net and of the manner in which it subserves the organism in its natural environment.

Tuesday, September 12.

JOINT DISCUSSION with Sections I (Physiology) and K (Botany), on *Genetics* :—

Prof. J. S. HUXLEY.—*Physiological genetics* (10.0).

Prof. R. R. GATES, F.R.S.—*The general nature of the gene concept* (10.30).

Dr. C. C. HURST.—*The significance of genetics in evolution* (11.0).

The science of genetics has advanced rapidly during the last decade. The mechanism of heredity and variation, which was unknown to Darwin, has been revealed to us by the microscope. Experiments show that morphological, physiological, and psychological characters are alike organised by sets of genes carried by the chromosomes of the cells. Consequently it is now possible to re-arrange the old indefinite Linnean species into definite genetical species which are experimentally determinable by their gene-chromosome complexes. Thus taxonomy becomes an exact science and the genetical species provides a measurable unit of evolution.

The gene is the unit and basis of life and progressive evolution can be traced from the monogenic species of Bacteriophage of molecular size to the polygenic species of the Primate Man carrying a genechromosome complex which produces a conceptual mind. The exercise of this in scientific research is rapidly bringing power and freedom to man by gaining more control over nature and life. Experimental hybridisation of genetical species

and bombardment of their germ-cells by X-rays have already created numbers of new species and forms, and the time is at hand when natural selection can be replaced by human selection and man himself will be able to control evolution and in a large measure determine his own destiny.

Dr. K. B. Blackburn.—*The synthesis of species* (11.20).

Recently new true breeding species have been produced experimentally by crossing two other species and these do not, as a rule, produce fertile offspring when backcrossed with their parents. The secret of their origin is revealed by their cytology. Lack of fertility in a species hybrid is often due to incompatibility of the chromosomes of the parents, but most of these new species have been produced by a doubling of the complete complement of the hybrid, thereby producing two equivalent sets to pair at meiosis. This gives the pure breeding character which marks them off from the hybrid swarms produced from crosses which are more or less fertile in the first instance. Such forms have been produced by crossing species (*Primula Kewensis*, *Nicotiana digluta*, *Crepis artificialis*) or even genera (*Raphano-Brassica*, *Ægilotricum*). Similar naturally occurring forms have now been recognised (*Rosa Wilsoni*, *Spartina Townsendii*), but the crowning piece of evidence for this as a natural method of species building is the production by Müntzing of plants indistinguishable from the common hemp-nettle (*Galeopsis tetrahit*) by crossing two quite distinct species, *G. pubescens* and *G. speciosa*.

Dr. Irene Manton.—*The analysis of species* (11.40).

Col. C. J. Bond, C.M.G.—*Hormones and genetics* (12.0).

The importance to physiology of the particulate discontinuous nature of the heredity process, as established by Mendel.

Diabetes a familial disease ; the pancreatic defect on which the disease depends is heritable. Treatment with insulin ameliorates symptoms, but does not remove the defect. Effect of this on racial welfare.

The evidence derived from a study of binovular twins, one of which may be a Cretin, or achondroplastic dwarf, and the other normal, throws light on the genetic factors concerned in thyroid and pituitary abnormality.

Tissue cell susceptibility to hormonic influences may vary on the two sides of the body. Examples. The gynandromorphic pheasant. Asymmetrical spur development in hens. Asymmetric polydactyly in fowls. Gynandromorphism in insects.

Acquired immunity and genetics. The immunity reaction in bacterial or coccal infections compared with that in virus diseases. The influence of size of the infecting agent on the permanence of the reaction. If cell descendants (not offspring) are to remain immune, the nuclear heredity mechanism of the somatic cell must be concerned in the reaction.

General Discussion (12.20). (Prof. F. A. E. Crew ; Dr. E. Ashby ; Mr. J. T. Cunningham ; Mrs. C. B. S. Hodson.)

Afternoon.

Mr. Michael Graham.—*Prediction of North Sea cod fisheries* (2.15).

It is known that fluctuations in the yield of certain fisheries, e.g. herring, plaice and cod, in the North Sea are largely determined by the degree of

success in survival of broods some years previously. The proportion of particular broods is estimated when the fish are large enough to be taken in trawls. Having found that the important fisheries depend on fish of a restricted age, say, five to six years old, estimates of the yield at that age can be made some years in advance, from the abundance of fish of, say, one to two years old.

The particular case considered, the cod in the North Sea, is interesting in that:

(1) The area populated by small fish is so extensive that adequate sampling of small cod can only be obtained in the trade statistics of landings, cause being shown for considering the magnitude of certain seasonal changes in the statistics as a measure of brood strength.

(2) The age of the cod (by which landings of small cod are related to brood years and to subsequent yield of large cod) has to be obtained indirectly, from size ; partly because of the said sampling difficulty and partly because the more usual determinations of age from scales or otoliths are unreliable for this fish (in the North Sea). The necessary analysis involves somewhat unconventional methods, which are, however, justified by the high correlation found. (See (3).)

(3) Formulæ are deduced from the investigations of (1) and (2) and relate brood strength to subsequent yield per unit of fishing power, in a perfectly rigid manner, so that, up to a point, the prediction is precise and depends merely on arithmetic (its precision being estimated by prediction of the 'probable error'). High correlation has been found between the estimate of brood strength and subsequent yield.

Mr. E. Ford.—*Growth in length and change in form with increasing age in fishes, especially the herring* (2.45).

The communication deals with changes in form brought about by the different rates at which the various parts of a fish's body increase in length during the transition from a transparent larva to a fully scaled adolescent, and with the subsequent growth in length of the body as a whole, by the addition of progressively diminishing annual increments throughout life. Simple mathematical treatment of observed data raises interesting questions in phylogeny and ontogeny, and suggests a convenient method for the comparison of growth in different geographical regions.

Dr. C. H. O'Donoghue.—*Jasper Park, Rocky Mountains: its biology and fisheries* (3.15).

In 1925 the Biological Board of Canada requested the author to investigate the lakes in Jasper Park with a view to improving their fishery value. It was considered worth while to conduct the examination on broad lines, since no similar survey had been made within a radius of 2,000 miles, and the mountainous character of the country, its altitude and essentially virgin conditions made it unique in North America. This report covers two summers' field work and their results. One noteworthy problem was the entire absence of fish from the Maligne-Medicine drainage system. The answer to this question was found in the peculiar geological conditions of the outlet of this system into the Athabasca valley, whereby the system is cut off from the possibility of fish immigration. A fairly full investigation of the physical and chemical constitution of certain types of lakes was made and also a survey of their flora and fauna. Resulting from the survey

various suggestions were made, among them the planting of the Maligne-Medicine drainage area with Speckled Trout, *Salvelinus fontinalis.* Most of the experiments were successful, and a report made for the Board this year states : 'The stocking of the Maligne-Medicine system with speckled trout has given results second to none in the history of fish culture.'

SECTION E.—GEOGRAPHY.

Thursday, September 7.

Mr. M. Gimson.—*The water supply of Leicestershire, with special reference to human settlement* (10.0).

The subsoil of Leicestershire consists mainly of impervious clays—the Lias Clay and the Keuper Marl—in which water, when obtainable at all, is found at considerable depths.

Water near the surface is only found in :

(*a*) The Valley Gravels.
(*b*) The Glacial Gravels.

The former are found on each side of the principal rivers, and provide good sites for villages, when in the form of River Terraces, with water easily accessible.

The latter occur mainly on the higher ground, where the glacial covering still remains. This covering is principally Boulder Clay, but water-bearing sands and gravels are found associated with it in places.

Such sands and gravels form the only source from which water could, in early days, be readily obtained away from the main watercourses, and their influence in deciding the position of settlements is clear. It is particularly well shown in East Leicestershire, where, almost without exception, villages on the uplands are situated on small isolated patches of sand or gravel, and where in the southern portion there are many such villages, while in the northern part large areas of the higher ground are scantily populated, owing to the glacial covering being devoid of sand or gravel.

Miss G. M. Sarson.—*The growth of population in Leicester* (10.45).

The city of Leicester is situated in the valley of the river Soar, from which the ground rises eastward and westward. To the east are the Spinney Hills and the Victoria Park, the former 264 ft., the latter 289 ft. high, while westward are the Dane Hills, over 200 ft. above sea level. The oldest part of the city was situated on a gravel terrace on a spur 190 ft. to 210 ft. high, on the right bank of the Soar, which formed a boundary and a defence on the western side. To the north the ground sloped downwards to the marshy meadows of the Soar, 20 ft. lower than the gravel terrace. The Fosse Way entered from the north-east, to cross the river at the present West Bridge, and afterwards passed in a south-westward direction towards High Cross. In mediæval times life centred round the abbey and monastic houses. These declined in importance, but there was an increased trade in the markets, the chief of which—the Saturday market—was in the south-east corner of the town. Here the agricultural produce of the district was sold, for Leicester was the market centre of the county.

The population until the end of the seventeenth century has been estimated

at 5,000 people, but by the end of the next century the number increased to 16,953, due chiefly to the establishment of the framework knitting industry, and the beginning of the manufacture of boots and shoes. The latter half of the nineteenth century was a time when the greatest increase in population took place, and by 1921 the census statistics show that Leicester had a population of over 240,000. Other industries, in addition to the two chief occupations of hosiery and boot and shoe manufacture, are the making of machinery, manufacture of optical instruments, and printing. Thus, after remaining through many centuries a community of approximately 4,000 people, the city developed from a small country town into one of the most densely populated centres of modern commerce of the north-east Midlands.

Dr. P. W. Bryan.—*Preliminary survey of land utilisation in the City of Leicester* (11.30).

Mr. H. H. Peach.—*Regional planning and the Leicester district* (12.15).

The study of the cultural landscape and value to town and country planning. The necessity of study of planning, not only by experts but by the ordinary man, to save the country from disfigurement. Schultz Naumburg's studies on cultural landscape referred to.

Rapid development of land by economic circumstances and breaking up of old estates, where planned development used to be carried out, is having serious effect on landscape. Difficulties in planning by local authorities and distrust of same felt by many. New Town and Country Planning Bill and what can be done. Local problem of Charnwood Forest. Economic value of planning in development. Leicester rapidly developing town, clean, little planning, much ribbon development.

Dreariness of new suburbs. Officials and destruction and disfigurement of trees. No control of elevations. C.P.R.E. and Advisory Panel system, a help towards suitable building. Local housing schemes compared. Parks and allotments. Need of walking ways. New Walk example. Advertisements and planning. Curse of enamel sign. Industry finding need and value of taste in design and lack of training in schools, a vital matter in planning. Engineer and expert often spoil good plans by bad taste. Leicester City Council and Art Advisory Committee. Need of more co-operation and neighbourliness in building and planning.

Afternoon.

Tour of the City of Leicester to study land utilisation and general position.

Friday, September 8.

Dr. Vaughan Cornish.—*The visualisation of landscape* (10.0).

The science of physiological optics, which has been long and successfully pursued, provides reliable information as to the extent of the surrounding sphere which it is possible for the eye to perceive ; the distance to which stereoscopic vision extends ; the perceptible contrasts of light and colour ; and, generally, as to that which it is possible for our eyes to recognise in the surrounding landscape—*when we try*.

The pleasurable, or æsthetic, impression of landscape has, however, relatively little to do with what we can see when we try, but, on the contrary, depends upon what we notice when we make no conscious effort. The investigation of this branch of psychological optics is therefore indispensable to the creation of an æsthetic science of scenery. In the present paper the author describes the methods which he has employed to ascertain the modes of selective action by which the eye unconsciously provides the ordinary man with a vision of the landscape which is, in fact, an artistic composition.

The review includes examples relating to impressions of tone, colour, form, magnitude, multitude and movement in the landscape of different climates and latitudes.

Mr. J. A. Steers.—*Scolt Head Island: a study in physical geography and ecology* (10.45).

Scolt Head Island, on the Norfolk coast between Hunstanton and Wells, affords excellent scope for the study of (1) constructional coast forms, (2) comparatively rapid erosional changes, and (3) the relations of plant ecology to shore-line studies.

It is a National Trust area, and is best known as a bird reserve. But the geographer has much to interest him both on the island and along the adjacent coast.

The origin of the island is rather uncertain, and is here discussed. One of the more interesting problems that yet await solution is the possible light that archæology may throw on this problem. Two ancient encampments are very close to the area, one being in marshland. Their excavation may afford very interesting results. This island is a long sand and shingle formation, with numerous recurved ends running back from it. Within the main beach and between the laterals is an admirable development of saltmarshes, with characteristic flora.

On the mainland side of the creek which separates the island from the land are some other shingle ridges which have apparently been built in a direction (i.e west to east) opposite to that of the main island. They are directly comparable with the ridges still forming on the distal end of Brancaster Golf Links.

Near by is a submerged forest, the future investigation of which should afford some data for the chronological history of the island.

Col. M. N. Macleod.—*The mapping of the Empire* (11.30).

The mapping of the Empire has barely begun, and the lack of maps is a serious obstacle to ordered development. Much money has been wasted in the past on this account.

To remedy this situation the first thing is to find the money. Surveys are most necessary in those colonies least able to pay for them. Progress will be slow unless the money can be borrowed. The Colonial Development Fund was established for such purposes. Having found the money, the next thing is men. Enough trained surveyors are not available. Air survey provides a new and suitable technique, but is hampered by the high cost of photography and the lack of geodetic foundation.

Geodetic surveys of the Empire are particularly backward and their more energetic prosecution is especially necessary. Finally there is the question of revision. Every scheme for systematic survey should include provision for periodical revision.

Lt.-Col. A. B. Clough, O.B.E.—*The preparation of maps and illustrations for geographical articles and theses* (12.15).

Geographers wishing to illustrate their articles by maps can either :

(1) Draw the map *de novo* from their own survey material or by copying or tracing from existing maps ; or

(2) Use an existing map as a topographical base on which to overprint their special information.

In all such cases where they are preparing drawings in any form for reproduction, some knowledge regarding the processes of reproduction will be found very helpful.

In the case of (2) above, the Ordnance Survey can supply impressions in non-photographic blue of detail or water or contours or of any combination, on which the special material can be drawn in its correct position. This special drawing can then be reproduced as an overprint in any colour on the chosen map sheet, the basic topographical detail being printed either in its normal colouring or in grey, dependent on whether it is desired to emphasise or not the special information in comparison with the topography.

For Great Britain a choice of Ordnance Survey maps ranging between the large scale 1/2,500 to the small scale 1/million is available.

When compiling material for subsequent reproduction in conjunction with an Ordnance Survey map, it is wise to use the appropriate Ordnance Survey map as the key and not to use other maps of nominally the same scale. Otherwise subsequent difficulties in register may ensue.

Afternoon.

Prof. Ll. Rodwell Jones and Mr. F. H. W. Green.—*Rainfall in Kenya and Uganda* (2.15).

In Kenya there are some 230 rainfall stations, of which only 80 have records for a period of more than fifteen years. The corresponding numbers for Uganda are 35 and 14.

In both countries the stations are unevenly distributed, and in some cases the records obviously unreliable. Even so it seemed possible to construct maps which should aid a rapid assessment of the rainfall conditions and do no serious injustice to the general facts.

A 1/250,000 contoured map exists for much of the area, and the isohyets were drawn with constant reference to the relief. The usual methods of interpolation were used in respect of the records of short-period stations. Maps showing distribution by months for the long-period stations have also been prepared. Amongst much else it emerges definitely that a rain shadow is formed by the Eastern Highlands, and that there is a difference in the distribution type for places in the same latitude but on opposite sides of the Northern Rift.

From hourly velocity readings windroses were prepared for the three first-class stations for selected months.

At Kampala the chief influence appeared to be the land and sea breezes of the northern verge of Lake Victoria. The same phenomenon, for definite hours, causes a deflection in the otherwise monsoon directions evinced at Zanzibar.

Mr. E. W. Gilbert.—*The human geography of Mallorca* (3.0).

Mallorca, the largest of the Balearic Islands, is 1,350 square miles in extent, almost the same size as the county of Cornwall, and contained about

270,000 inhabitants according to the census of 1920. The object of this paper is to examine the distribution of population in relation to the physical and economic geography of the island. Mallorca can be divided by its relief into four regions. The principal feature of the relief is a range of mountains, 45 miles long and about 10 miles broad, which form the north-western part of the island and rise in places to heights of nearly 5,000 ft. The south-east of the island contains a range of hills of much lower general altitude than the northern mountains, the maximum height being only 1,500 feet. These two regions are separated by a wide central plain, whose general level is interrupted by a fourth region, the isolated mass of Randa. The four major regions can be subdivided on the basis of the natural and cultivated vegetation. The whole of the central plain is cultivated and forms a vast orchard of fruit trees, principally almonds. The climate makes irrigation essential, by wells on the plain and by tanks in the mountains.

Palma is the principal settlement and with its suburbs contains nearly one-third of the population of the island. With the exception of Palma there are no large coastal settlements. The area of greatest density of population occurs along the southern foot of the northern mountains. A marked feature of the distribution of population in the central plain is the absence of hamlets and villages, as population is concentrated in small towns containing 1,500 or more inhabitants. The population is, however, more dispersed than it was a hundred years ago.

Prof. C. Daryll Forde.—*Variations in the native economy of arid regions* (3.45).

A comparative review of the native economies of the arid regions of the world shows clearly that the general climatic conditions are of less significance than (*a*) particular physiographic and biological conditions, and (*b*) the cultural history of the larger areas of which these desert regions form a part. Climatic divisions into ' hot ' and ' continental ' deserts and gradations from winter to summer precipitation appear to be largely irrelevant to the classification of native economies.

Areas climatically and vegetationally closely similar exhibit fundamental contrasts. Even at the lowest economic levels the peculiar features of a particular habitat are all-important. The Coahuilla of the Mohave Desert and the Bushmen of S.W. Africa are the one almost entirely collectors of wild fruits and the other dominantly hunters. This differentiation is not dependent on divergence of general physical conditions but on the sharp contrasts in the relative abundance of particular forms of plant and animal life.

Every type of economy is represented in arid areas, and the introduction of various domestic animals and types of agriculture has profoundly modified the distribution and density of settlement and the seasonal rhythms of activity and settlement. Food-gathering economies have long been largely extinguished in the Old World deserts of the northern hemisphere, and comparisons of the Badawin and Saharan Berber economies on the one hand with those of the Bushman and Aranda on the other, and of the Kazak economy in southern Turkestan with that of the Paiute of the Great Basin, bring out some of the profound consequences of pastoralism and access to marginal settlements of higher culture. The penetration of higher economies is often partial and is sometimes delayed by cultural factors. Maize cultivation under conditions of natural flooding has been practised for more than a millennium in parts of the arid region of south-western U.S.A. and

northern Mexico, but the special physiographic conditions have been utilised only over a relatively small and fluctuating area. Considerable areas in which springs and flood waters afforded opportunities for agriculture were occupied by non-agricultural peoples. This region, in which sheep pastoralism has developed among the Navajo in post-Columbian times, affords an interesting example of the co-existence of three contrasted economies practised by different peoples occupying a single region.

Saturday, September 9.

Excursion to Holwell Iron Works and the Melton District.

Sunday, September 10.

Excursion to Leicester, Uppingham, Peterborough, Wisbech.

Monday, September 11.

PRESIDENTIAL ADDRESS by Rt. Hon. LORD MESTON, K.C.S.I., on *Geography as mental equipment* (10.0). (See p. 93.)

Sir EDWARD A. GAIT, K.C.S.I., C.I.E.—*Races and languages of India* (11.15).

India contains a remarkable diversity of languages and peoples. The 223 indigenous languages belong to four distinct linguistic families—Dravidian, Austric, Aryan and Tibeto-Chinese. There is nothing definite to show where the first two originated, but the last two were brought by immigrants from the north-west and east respectively. Aryan languages are now spoken by three-quarters of the population.

The 'Aryan' physical type predominates in the north-west, and the Mongoloid in the east. The people in the south, known as 'Dravidian,' are a composite race. North of the 'Dravidian' there is a blend, on the west with Aryan and on the east with Mongolian.

The post-Aryan invasions did not much affect the physical type, but those of the Afghans and Mughals brought the Muhammadan religion now professed by one-fifth of the population.

The existing divisions are based mainly on religion and language. The most notable is that between Hindus and Muhammadans. The linguistic groups may be regarded as distinct races, but in their religion and traditions the Hindus throughout India have a bond of union which has been strengthened by the wide diffusion of English which serves as a *lingua franca*.

DISCUSSION on *India* (11.45).

AFTERNOON.

Sectional Lunch (1.0).

Prof. F. DEBENHAM.—*Report on the Polar Year* (2.30).

Dr. E. H. SELWOOD.—*Classification of communities by means of occupations* (3.0).

The standard set up last year at York that if 40 per cent. of the workers are engaged in any one occupation it was sufficient to characterise that

community is maintained in Scotland and Ireland. In the latter agriculture rises in the west even to 90 per cent. of the total workers. The Dublin area differs from the remainder of the southern part of the island.

'Craft' (manufacture) is confined almost entirely to the north-east, the Dublin, Waterford and Cork areas. There is, however, one town, Clara, which in composition is strikingly like Buckfastleigh in Devon.

In distribution the Personal Attendants class differs from that of the other island; whereas in England and Wales the average in rural areas is about 14 per cent., in Ireland an average of only about 5 per cent. is noted.

Attention is called to the correlation between occupations—in some cases the coefficient rises even to $+ 0 \cdot 60$, pointing to common governing factors, and it is hoped that as these governing factors are isolated, a more definite determination of governing conditions may be made.

Tuesday, September 12.

Dr. H. C. Darby.—*The geographical conceptions of a medieval bishop* (10.0).

The scholarship of the Middle Ages was far from being the narrow superstition we are sometimes told it was, and fewer individuals demonstrate this better than Robert Grosseteste (*c.* 1175–1255). He stands a representative figure of the medieval renaissance of the twelfth and thirteenth centuries. Embodying Ancient Greek and Arabic learning, his writings are characterised by their appeal to reason as distinct from tradition, and by their critical faculty. In them is to be found the scientific geography of the time—discussion of the sphericity of the earth, the distribution of land and sea, causes of regional differences on the earth's surface, meteorological problems, and the features of oceanic phenomena. Though not free from theological preoccupation, the discussion of these topics by Grosseteste presents an intelligible view of contemporary geographical theory, in itself an intelligent achievement.

Dr. L. Dudley Stamp and Mr. E. C. Willatts.—*Changes in the utilisation of land in the south-western part of the London Basin, 1840–1932* (10.45).

This paper represents an attempt to use one of the first sheets to be published by the Land Utilisation Survey of Britain (1-inch, England and Wales, No. 114, Windsor) as a starting-point for a detailed study of changes in land utilisation in the south-western part of the London Basin. From the MSS. records kindly made available by the Ministry of Agriculture and Fisheries of tithe apportionment made under the Tithe Act of 1836 it has been possible to identify the individual fields and so to construct, for certain parishes, a land utilisation map for the period about 1840. The parishes especially considered in the paper are White Waltham, Berkshire (Chalk, Reading Beds and London Clay); Winkfield North (mainly London Clay, comparatively remote from the influence of London); the group formed by Egham, Wraysbury, Staines, Ashford and Stanwell (forming a strip from the Bagshot Beds, through London Clay to the Thames Gravel and alluvium); Ashtead and Headley (Chalk and Plateau Gravels of the North Downs and London Clay).

Apart from housing development, there has been, contrary to common generalisation, remarkably little change in some areas—even an extension

of arable land—but enormous changes in other areas, especially on tracts of heavy soil. Amongst the factors specially considered have been soil, slope, accessibility, value and desirability for residential purposes and economic factors consequent upon the growth of London. A further extension of the work has been possible in one or two areas by using seventeenth-century manorial maps.

Prof. E. G. R. TAYLOR.—*Economic geography of early Stuart England* (11.30).

The economic problems of England three centuries ago, as they are discussed in the literature of the period, are strikingly similar to those discussed in newspapers to-day. Over-population, the decay of rural life, urbanisation, unemployment, the burden imposed by high wages and rising prices on the upkeep of great estates, the ruin of the roads by heavy traffic for which they were not designed, the dangerous depletion of timber supplies, 'unfair' foreign competition in the fishing industry, free trade and the balance of trade, the need for improvement of internal water-ways, for the control of flood-waters, for the reclamation of fens and marshes, for the improvement of methods of husbandry—all these had their geographical aspects, and their brief discussion is intended to throw light on the geography of early Stuart England.

Mr. H. C. K. HENDERSON.—*Downland agriculture of East Sussex* (12.15).

During the last 150 years several surveys of land utilisation on the South Downs have been made. The first is an unfinished map of Sussex, four sheets of which were published in an incomplete state in 1780 : the published map is on a 2-inch scale, and was constructed by Yeakell and Gardner in competition for the prize for large-scale county maps. Between 1836 and 1851 the tithe maps were constructed for each parish, and the roll in most cases records land utilisation ; fortunately Sussex was almost entirely tithable. In 1875 the Ordnance Survey issued the first edition of the 25-inch maps of Sussex, together with area books which include utilisation details. The extent of arable activities and the crop distributions have been mapped on a 6-inch scale for 1931, and also, for part of the region concerned, for 1918 and 1927, by the writer.

Each of these larger-scale surveys has been reduced to the common scale of 1 inch to 1 mile, whence a direct comparison of the varying extent of arable cultivation can be obtained.

Finally, a statistical summary of crop distributions relative to various factors has been compiled from the actual field distributions of crops in 1931.

AFTERNOON.

Excursion to Charnwood Forest.

Wednesday, September 13.

Mr. K. C. EDWARDS.—*Some aspects of the Luxemburg iron industry* (9.45).

For more than a century before the exploitation of the *minette* ore of Lorraine (mainly since 1870) there existed in central Luxemburg one of the important iron-working regions of Europe. The mineral was obtained

from alluvial deposits and the workings, though widely scattered, were situated in relation to the forests and streams. Furnaces and forges were often far apart, and coal and coke were not in general use until after 1865.

The working of the *minette* ore in the southern extremity of the Grand Duchy caused a striking change in the location and character of the industry. The delay in this development was due almost as much to the lack of transport facilities as to the fact that the ore demanded special treatment. The interesting sequence of changes accompanying the evolution of the industry is shown by a study of the works at Fischbach (1768), Eich (1845), and Esch-sur-Alzette (1870).

The progress of the modern iron and steel industry has exercised important effects upon the distribution of population, emigration and immigration, agriculture, and upon economic relations with the neighbouring countries.

Mr. R. E. Dickinson.—*The metropolitan regions of the United States of America* (10.30).

(1) The distinctive characteristics of a metropolitan city. The criteria to be adopted in selecting cities which have attained some degree of metropolitan development (population, *per capita* sales of manufactures, wholesale and retail goods, distribution of merchandising space, markets, Federal Reserve banks).

(2) On the basis of these criteria, the selection and classification of those cities which have attained metropolitan proportions.

(3) The character and extent of the 'zones of influence' of a metropolitan city, illustrated with specific examples from the United States (twin cities, Chicago, Philadelphia).

(4) The areas served by the metropolitan cities of the United States in some of their distinctive functional capacities, based on an examination of maps showing areas of supply of live stock and grain markets, wholesale trade areas, areas served by district branch houses of representative companies, Federal Reserve districts, newspaper circulation areas, etc.

(5) The delimitation of composite metropolitan regions, and an attempt to classify the metropolitan centres, on the basis of function and growth, in relation to the extent and character of the regions they serve.

Miss H. G. Wanklyn.—*The Niemen River: a neglected waterway* (11.15).

The Niemen River rises in the marshes of White Russia and flows into the Kurisches Haff just south of the Baltic port of Memel. It could be made navigable as far as the Russian village of Naujas Svierzenes, about 892 kilometres from its mouth, but as yet only the lower reaches have been regulated.

Before the war the Niemen basin was the natural hinterland of the German port of Memel, as wood, the main export from Memel, was floated down the Niemen from the forests of White Russia and Russian Poland.

By the re-alignment of frontiers after the war, the transit trade of the Niemen River was interrupted by two frontiers: that between Soviet Russia and Poland, and that between Poland and Lithuania. The river also forms the boundary between Germany and Lithuania. The multiplication of frontiers in this area has been especially disastrous, as owing to the dispute between Poland and Lithuania over the Vilna region there has been a complete severance of relations between the two countries for the last fourteen years.

Passenger traffic between Poland and Lithuania is diverted through Latvia,

and the doubtful absorption of the German Memel territory by the new state of Lithuania has also added to economic difficulties.

In consequence the dredging of the Niemen has been neglected and the timber trade has declined steadily. The victim of bad political relations has been the Memel port, whose chief export commodity is now relegated to the Vistula waterway.

The undesirability of the boycott is dawning on both governments. Poland, by seizing the Vilna district by force, has stultified its economic development and deprived it of its natural outlet. Lithuania has lost the greater part of her transit trade.

SECTION F.—ECONOMIC SCIENCE AND STATISTICS.

Thursday, September 7.

Sir GEORGE BUCHANAN, K.C.I.E.—*The economic position of Burma* (10.0).

Burma has always been famous for its rice, but a tremendous impetus was given to paddy cultivation by the opening of the Suez Canal in 1869, which, by lowering freights between East and West, greatly stimulated the demand for rice in Europe.

Burma has in half a century reclaimed and brought under cultivation for paddy 12½ million acres of land, and is to-day the greatest rice exporting country in the world, with an annual export of 3 million tons of cleaned rice.

This great work carried out entirely by Burmese peasantry; initial advantages being large areas suitable land; regular rainfall; single crop over whole area, and cheap labour from India. No capital in country; cultivators financed by Indian moneylenders, supplemented by co-operative societies, which began well but ultimately collapsed. Milling of rice and its export in hands of Europeans and Indians. World distribution and value. Other agricultural products and development of oil and teak industries. Total value of Burma's export trade and how distributed. Burma not a manufacturing country and dependent on outside sources for all manufactured goods. Extent and value of import trade, penetration of Japan in textile requirements.

The political situation and introduction of politics in country not conducive to happiness and prosperity of people.

Revenue and expenditure and balance of trade.

Disastrous effect of world crisis and unfortunate dependence of Burma on one staple trade. Increasing competition with other rice-producing countries. Seventy per cent. of population engaged in agriculture, principally paddy cultivation; unless fair price obtained for paddy, which again is dependent on price of rice in world's markets, whole economic structure must fall to ground and people revert to primitive standard of living. Alternative: development of other agricultural products and make country self-supporting by creation of industries; this difficult because no coal in country, nor possibility of hydro-electric power in Lower Burma at economic price.

PRESIDENTIAL ADDRESS by Prof. J. H. JONES on *The Gold Standard* (11.30). (See p. 109.)

Friday, September 8.

Prof. ARNOLD PLANT.—*Economic theory of patent and copyright law* (10.0).

There has not so far been sufficient discussion by economists of the economic effects of the systems of patents for inventions and of copyright for literary and artistic production. Two contrary assumptions have been made concerning the relationship between the patent system and the display of inventiveness. On one side it is asserted that without patents there would be no inventions; the profusion of innovation in our own time in fields which fall outside the range of patent legislation suggests that this is unlikely. On the other side it is assumed that the patent system has little influence upon the amount of inventing that takes place, but that it serves to direct inventing into the fields of greatest social advantage; an assumption which in turn conflicts with normal expectations concerning the disposition of the factors of production in a monopolistic regime. The conditions making for the display of inventiveness are analysed and the patent system is shown to influence the amount of invention of the type that is induced by changes in economic conditions. Light is shed upon these questions, and upon the relation between variations in prosperity and variations in the output of 'inventions,' by an analysis of the statistics relating to applications for patents in various countries. There are reasons for concluding that the patent system results, at least in the short-run, in misdirection of the factors of production. The arbitrary and clumsy nature of this system of encouraging an infant industry is examined.

The closely parallel copyright legislation is shown on economic analysis to be equally arbitrary in its provisions and lacking in clear basic principle. The peculiar treatment of the right of mechanical reproduction of musical compositions, under existing English law, is contrasted with the provisions relating to literary and artistic works, as compared with the device of the 'Licence of Right' in post-war patent legislation. An extension of the application of this device would probably reduce the amount of restriction of output made possible by this type of legislation. There are, however, administrative difficulties.

Sir ARNOLD WILSON, K.C.I.E., C.S.I., C.M.G., D.S.O., M.P.—*The effect of Suez Canal dues upon inter-continental trade* (11.30).

A statistical comparison of the incidence of tolls—both on vessels and on cargo passing through the Suez and over the Panama Canals respectively—shows that dues levied differ by nearly $33\frac{1}{3}$ per cent. in favour of the latter. An examination of the figures indicates that the difference is sufficient to divert traffic between London and certain Australian and Far Eastern ports, and between New York and other ports.

The method of calculation of the dues in each case is contrasted, and it is pointed out that they are based in each case not on the weight or bulk of cargo carried, but on the carrying capacity of the ship. This tends to place an unduly heavy burden on raw material as compared with manufactured goods.

Monday, September 11.

DISCUSSION on *Technological and economic progress* (Mr. R. F. HARROD; Prof. J. A. S. WATSON; Dr. K. G. FENELON) (10.0).

Prof. H. M. Hallsworth, C.B.E.—*The work of development boards* (12.0).

Tuesday, September 12.

Prof. P. S. Florence.—*Types and supply price of entrepreneur and business administrator* (10.0).

Economists are still apt to assume that management is mainly in the hands of an entrepreneur highly sensitive to variations in profit. In reality there are to-day a number of types of business administrator in control of industry, many of them with weaker pecuniary incentives.

These types include the self-made entrepreneur, the head of a family business, the financier, the guinea-pig and ex-professional-man director, the ex-foreman, the ex-technician, and, finally, the trained administrator. Each type has different incentives and reacts differently to the vital problems upon whose solution large-scale efficiency depends. Each must be assessed differently in respect of efficiency in initiating large-scale expansion, in co-ordinating the several departments and functions of the firm, in re-investing capital, in making appointments, and in co-operating or combining with other firms.

The self-made entrepreneur often fails to adapt himself and his organisation to large-scale planning and technique ; his education, experience and individualist habits are not conducive to the successful co-ordination and reintegration of specialists or to co-operation with other firms. The family-head entrepreneur does not always wish to expand business in response to the chance of higher profits ; he has the fixed though high standard of living of the gentleman of leisure, and the chance of a higher supply price will not necessarily increase his output. The trained administrator offers on the whole the best hope that large-scale operations may be expanded with the same initiative that the entrepreneur displays when expanding his small-scale undertaking.

Mr. E. L. Hargreaves.—*The problem of business recovery* (11.30).

General view of industrial fluctuations. The different phases of fluctuations. The stage of recovery. The various explanations of how recovery occurs. The inadequacy of these explanations. The conception of an oscillation round an equilibrium level. The neglect of long period or secular movements. The various types of secular change and their interdependence. Relative rates of change of long-period factors. Interrelations of cyclical and secular movements. The explanation of the differences in different cycles. Historical considerations and some qualifications. Economic progress and future tendencies. Questions of policy. Conclusions.

Wednesday, September 13.

Mr. J. Sykes.—*Public expenditure and public works* (10.0).

The aim is to examine some of the fundamental arguments advanced for and against the policy of promoting public works during depression, with more particular reference to the contemporary situation.

Mr. Gilbert Walker.—*A rational and economic division of function between road and rail* (11.30).

Legal regulation of railway charges makes it profitable for road carriers to undercut the railways for all goods classed as General Merchandise, and to operate only where traffic is dense. A rational division of function should enable the railways to charge rates for General Merchandise competitive with road charges, and it should ensure that road carriers find it most profitable to compete for traffic where it is least dense.

The classification upon goods classed as General Merchandise must be abolished and the railways allowed to charge rates competitive with road charges. They must be permitted to discriminate against goods carried along the lighter traffic routes, and to close all unprofitable lines.

The railways will become smaller organisations ; the road hauliers will have to work less lucrative routes, and the competitive relations between traders will be disturbed. The alternative to this is a monopoly which must include all lorries run in competition with the railways. In either case the disturbance to vested interests may be great enough to make an economic division of function unobtainable.

If the existing and most uneconomic division of function cannot be avoided the railways must be protected from road competition by restricting road transport much more severely than is attempted by the Road and Rail Traffic Act.

DEPARTMENT OF INDUSTRIAL CO-OPERATION (F*).

Thursday, September 7.

Afternoon.

Discussion on *Organisation as a technical problem* (Chairman : Dr. E. F. Armstrong, F.R.S.) (3.0) :—

Major L. Urwick.—*Organisation as a technical problem.*

Importance of organisation. Principles which should govern human association of any kind can be studied as a technical problem irrespective of constitutional, political or social theory, the purpose of the particular undertaking or the personnel composing it. The work of Mooney and Reilly. Co-ordination as the main principle of organisation. The 'span of control': Graicunas' theory. Lack of recognition of the limitations imposed by the 'span of control.' League of Nations organisation. The British Cabinet. Methods of dividing up activities : the 'line' principle and the 'functional' principle. Effect of increasing specialisation, due to increased scientific knowledge on co-ordination. Subdivision and delegation of the work of co-ordination. The 'staff' principle. Two sets of factors to be studied in any scheme, the allocation of duties and responsibilities and the relations which result. The relations of a 'staff' offieer in the British Army. The effect of such relations in the co-ordination of a single function : supply. The co-ordination of all functions in a British division. A parallel problem in industry : purchasing. Translating technical principles into operating practice. The problem of personalities. The historical approach : an army example. The importance of comparative study : an industrial parallel of to-day.

Mr. A. B. Blake.—*Trade associations and combinations.*

(1) Historical aspect.
(2) Extent and significance.
(3) Types of combination:
  A. Permanent.
  B. Terminable.
(4) Aims, and inherent advantages and disadvantages.
(5) Legal status and legislative restriction.
(6) Formation.
(7) Conclusion: constructive uses and the current trend.

Friday, September 8.

Afternoon.

Discussion on *The rôle of accountancy in scientific management* (Chairman: Mr. Alfred Salt) (3.0):—

Mr. F. R. M. de Paula.—*The rôle of finance and accountancy in the management of large business combines.*

The new problem that has arisen by the introduction of the modern large-scale organisation. Successful administration, management and control are absolutely dependent upon a sound organisation throughout.

The administration of a large business combine, with its wide-flung and countless ramifications, is affected by every movement in the economic life of the world.

The point of action is often far removed from the seat of management. The problem is how such an organisation is to be successfully managed and controlled. Management itself is becoming a new science. Finance is the basis of industrial enterprise. Finance, including accountancy, must be one of the main divisions of the organisation of a large business, the others being production, purchasing and selling. The placing of the finance division in the organisation of a business. The functions and responsibilities of the finance division and the part it should play in control and policy decisions.

The accountancy organisation and the interlinking of same with a system of budgetary control, costing and statistical records. The way in which this organisation should be used in the management of such a business. The type of personnel required and their training. An outline of the organisation of the finance division, centralisation and decentralisation. The great need for speed in the production of figures, reports, etc. The objects of a budgetary control system.

Prof. Wm. Annan.—*The rôle of accountancy in the average business.*

Introduction.—Post-war industrial conditions outcome of invention, scientific discovery, world-wide competition and high taxation. Industrialists have sought to overcome adverse conditions by combination and formation of large units.

Classification of business.—Big business favoured by Government and Trades Unions. Encouragement of mergers and holding companies. Reaction towards individualism and average-sized business. Proportion of whole country's trade carried by such.

Need for statistics.—Statistics necessary for average-sized business as for large concerns. Possible without expert staff and expensive equipment if

book-keeping system properly planned. Rôle of accountancy to plan system and provide figures to guide principal. Freedom to concentrate on manufacturing (or buying) and selling essential.

Education of book-keepers.—Methods of preparation of statistics insufficiently emphasised by current text-books. Elaboration desirable. Meantime, under proper supervision, book-keepers can meet requirements.

Kinds of statistics.—No general forms. Each business own peculiar problems. Attitude of owner and book-keeper. History of specific case. Statistics produced without extra cost. Main statement comparison of Working Capital monthly, and monthly Manufacturing or Trading and Profit and Loss Account. Examples given and method of compilation explained. Budgeting for sales, estimates of gross profit, expenses and net profit, with proper form of standard costs. Periodic comparison with actual results. All a preventive against price-cutting and ultimate bankruptcy.

Monday, September 11.

Afternoon.

Discussion on *The psycho-physiological requirements of modern factory equipment, including particular instances of applied physiology and psychology* (Chairman : Sir Henry Fowler, K.B.E.) (3.0) :—

Mr. G. P. Crowden.—*The practical value of physiology to industry.*

Physiology, the medical science which deals with the working of the normal healthy body and the daily needs of man, has a dual field of application in industry, namely, to the worker in relation to his work and to the products of manufacture. Nearly sixteen million men and women in England and Wales are engaged in industry, and the daily cycle of work, fatigue and recovery must be in equilibrium if the health, comfort and efficiency of these workers are to be maintained.

The execution of the work without undue fatigue ; the intensity and nature of lighting requisite for a given task ; the conditions of temperature and ventilation in factories, workshops and mines compatible with human comfort, efficiency and health ; noise, vibration, food and clothing in relation to occupation and environment—these are physiological problems some of which have been studied in this country and abroad, but much remains to be done.

The products of industry, lighting installations, heating and ventilating systems, boots, headwear and clothing for this country and the tropics, insulation in building and ship construction and passenger transport vehicles, manufactured food-stuffs—all these things are bought by consumers for their better health, comfort or efficiency, and therefore the physiological needs of man should be studied and understood.

Industrial science and physiological science should be working hand in hand—the latter prescribing and the former providing for the wants of man.

Dr. G. H. Miles.—*The human factor in relation to the design of factory equipment and machinery.*

Factory equipment and machinery has in the past been designed from the point of view of the engineer who desires to attain a definite mechanical result. Modern management is interested not only in the result, but in the efficiency with which the result can be repeated throughout each working day. An important factor in efficiency is the human being who controls

the machine. Designers of machinery and factory equipment should therefore take into account the limitations of those who will use the machinery and equipment. Some of the limitations are due to :—

(1) Fatigue, which may be caused by : (*a*) badly arranged controls or working positions ; (*b*) unduly heavy muscular effort ; (*c*) harmful posture, etc.

(2) Rhythm of machine operations which do not fit in with rhythm of worker.

(3) Working or observation points being badly placed.

(4) Attention being distracted by moving parts.

(5) Attention being distributed in cases where concentration is essential to efficiency.

(6) Frustration of effort owing to bad design, in setting up, stripping and cleaning machines.

Human effort can and does overcome many of the defects of machine design, but at a great loss of efficiency. The quality of work often suffers, and the wholly unnecessary strain is detrimental to human well-being. For the highest efficiency the machines should be designed to fit the human being. In cases where there are insuperable mechanical or process limitations, the workers should be specially selected to suit the peculiarities of the machine or process.

Tuesday, September 12.

AFTERNOON.

DISCUSSION on *What are the essential basic data for the organisation of economic distribution?* (Chairman : Mrs. ETHEL M. WOOD, C.B.E.) (3.0) :—

Mr. LAWRENCE NEAL.—*From the viewpoint of the retailer.*

In the triangle—consumer, distributor, producer—our basic knowledge is remarkably small. *Vis-à-vis* the consumer we have practically no market analysis of his purchasing power by areas or by commodities ; no assessment of major trends in habits of spending. Nor has there been any classification of shopping districts.

The internal structure of distribution has similarly remained unexamined. There are distributive costs in the sales organisations of the factory, in wholesaling, and in retailing. Further, the last-named subdivides into types such as the multiple chains, the departmental store, the small shop ; yet we know little about the present functions or the performance of each.

Vis-à-vis the producer, mass-distribution may be usefully viewed as the last stage in the chain of productive processes. It requires, therefore, a very real knowledge of the economy of the factory. The possibilities and limitations of a material or a product in manufacture ; the dependence of costs on the size and regularity of the market ; elasticity of demand and new uses—such questions can only be satisfactorily solved where there is co-ordination between production and distribution.

For a practical study of this subject attention might well be concentrated on actual examples of individual and successful experiment.

Mr. G. I. AKEROYD.—*From the viewpoint of the 'manufacturer-retailer.'*

Instances of the practical value of basic data obtained where manufacturing and distributing outlets are centrally controlled and co-ordinated.

SECTION G.—ENGINEERING.

Thursday, September 7.

Presidential Address by Mr. R. W. Allen, C.B.E., on *Some experiences in Mechanical Engineering* (10.0). (See p. 129.)

Mr. Wm. Taylor, O.B.E.—*Historical and engineering features of Taylor, Taylor & Hobson's works* (11.15).

Mr. John Chamberlain.—*The mechanisation of knitting* (11.30).

Although the invention of the first knitting machine by the Rev. Wm. Lee, of Calverton, Notts, in 1589, was a triumph of mechanical ingenuity, the machine was, of necessity, crude, and many scientific developments were required before the mechanisation of that type of machine could be achieved. On the contrary, the latch needle, invented by Matthew Townsend of Leicester, in 1849, was definitely adapted to mechanisation soon after its invention. Many types of machines were introduced in the nineteenth century, but mechanisation proceeded much more rapidly after this time, and, broadly speaking, developed on the following lines :—

(1) The replacement of manual operations by automatic devices.

(2) The development of scientific methods of loop forming and loop manipulation.

(3) The introduction of stop motions for yarn breakage, etc.

(4) The improvement in machine tools for knitting machine production.

The following table shows the extent of the progress made.

Date.	Apparatus or Machine.	Machine Details and Gauge.	Speed (Courses or Revs. per Min.).	Stitches per Min. per Operator.
To A.D. 1933	Knitting pins or crochet hook	—	—	200 to 300
A.D. 1589	Hand stocking frame	One-at-once, 12-gauge.	20 courses	1,920
A.D. 1775	Hand warp loom	20-in. wide, 12 needles per in.	20 ,,	4,800
A.D. 1864	Cotton's frame	Four-at-once, 30-gauge.	40 ,,	38,400
A.D. 1868	Latch needle circular machines	4 machines, 4 feeders, 600 needles.	20 revs.	192,000
A.D. 1933	Cotton's system	24 - at - once, 48-gauge.	70 courses	829,440
A.D. 1933	Locknit warp looms	2 machines, 100 in. wide, 30-gauge.	200 ,,	1,200,000
A.D. 1933	Circular machines	8 machines, 12 feeders, 1,200 needles.	27 revs.	3,110,800
A.D. 1933	Seamless hose machines	10 machines, 300 needles × 3½ in. dia.	200 ,,	600,000

Discussion (12.15).

AFTERNOON.

Visit to works of Messrs. Taylor, Taylor & Hobson.

Friday, September 8.

Mr. R. S. CAPON.—*The reduction of aircraft noise* (10.0).

Audiometer measurements have been made of aircraft noise in flight, and of the noise of airscrews and engines on the ground. The experiments are described and deductions are made as to the means by which the noise may be reduced.

It is shown that the airscrew noise depends primarily on the speed of the tips of the blades: lower tip speeds are therefore required for quietness. The improvement obtainable in this way is limited by the engine exhaust noise, which is about 80 decibels in cruising flight. Effective exhaust silencers of the baffle type can be made, but they may involve some increase of fire risk in the event of an accident. It is estimated that the noise level in a single-engined aircraft might be reduced to rather less than 70 decibels (approximately that in a train with open windows) by the use of an exhaust silencer and a low-speed airscrew.

Reduction of noise in cabins by sound-proofing the walls is briefly considered, and some reference is made to the reduction of aircraft noise heard on the ground.

DISCUSSION (10.30).

The film in engineering.—Opening Statement by Mr. H. E. WIMPERIS, C.B.E. (11.0).

Cinemaphotography is found to be an increasingly useful tool in scientific and technical investigations. It may be used in three quite different ways. The simplest of all is its use to record the rapidly changing indications on the dials of instruments in cases where it is impossible to have an observer, or where, if there were one, he could not make and record his observations quickly enough; an example is the 'automatic observer' used in the testing of single-seater aircraft.

Another use lies in the ability of the cinema camera to make at any desired speed a record of the position or attitude of some moving body, the films being afterwards measured up under a microscope. An example of this, again drawn from aeronautical engineering, is the study of the motion of the spin of a free flying model; another the study of the full scale motion of porpoising in a flying-boat.

The third method of using the film is to take slow-motion pictures of rapid movements so that they are easily followed by the eye, thus enabling the quality of the action to be studied or demonstrated—e.g., the study of the launching of an airplane from a catapult.

A series of short films prepared by the Empire Marketing Board are shown to illustrate some of the methods employed in aeronautical research, together with another Empire Marketing Board film illustrating the technical development of a motor transport train to open up undeveloped territories in Africa.

Examples:

Mr. H. E. WIMPERIS, C.B.E.—*Aeronautical research* (11.10).

Sir Henry Fowler.—*An oversea motor unit* (11.30).

Some five years ago, following certain committees, the Overseas Motor Transport Directing Committee was formed under the Chairmanship of Sir James Currie, K.C.M.G., K.B.E. The object of this committee was to investigate the question of motor transport in the Dominions and Colonies, in undeveloped areas which were not ready for railway transport. After considerable investigation the Committee, with financial assistance from the Empire Marketing Board and the Dominions and Colonies concerned, decided to build experimental 15-ton units capable of traversing difficult country, the design being largely due to a member of the Committee, Mr. Herbert Niblett, C.B.E., D.S.O.

The film shown is that of one of these 24-wheel vehicles, which has been successfully running in the Gold Coast since March 1933, and depicts very clearly not only the performance of the unit, but the various engineering difficulties which were met with and overcome by the unit.

Mr. W. Wilson.—*Testing electrical switch equipment* (11.50).

The kinema camera is destined to play an increasingly important part in the testing of electrical equipment. Its principal uses are first, the recording of the visual results of tests, more especially those effects which may be too transient for reliable detection by the eye ; and secondly, the keeping of a continuous record of instrument readings. Examples of the first category are breaking capacity and instantaneous carrying capacity tests on electrical circuit breakers, for which the kinema is specially useful for recording the emission of flame and the moving or springing of the various parts. One of the commonest visual phenomenon is the electric arc, and since the duration is short, it can be recorded by a simplified form of kinema camera capable of very high speeds, and taking only say 12 or 24 successive frames on a single glass plate. Half a dozen illustrations are given of records taken with the kinema and the high-speed camera, including a short circuit at a Grid sub-station, the blowing of a similar fuse by DC and AC short circuits, the operation of a lightning arrester, the flash-over of rotary converters and its extinction by a high speed circuit breaker, and the continuous recording of no less than 17 instrument readings simultaneously during the sea trials of an electrically propelled vessel.

Mr. Alec Rodger.—*Some psychological tests* (12.20).

This film though intended primarily to illustrate a number of the more practical tests used by the National Institute of Industrial Psychology, shows the application of the film to that side of engineering which deals with the selection of operatives. It also illustrates the use that can be made of the film completely to record definite examples of dexterity and quickness in manipulation, and in judgment, also to establish comparisons between alternative methods.

Afternoon.

Visits : (i) to works of Messrs. Mellor, Bromley & Co. Ltd.
(ii) to works of Messrs. Wildt & Co. Ltd.

Saturday, September 9.

Visit to works of Messrs. John Ellis & Sons Ltd., quarry of Mountsorrel Granite Co. Ltd., Hallgates Filter House of the Leicester City Council, and Cropston Waterworks Pumping Station.

Monday, September 11.

DISCUSSION on *Sewage treatment and disposal* (10.0) :—

Mr. J. DUNCAN WATSON.—*Introduction.*

One of the indispensable needs of a great city is a copious supply of potable water, but after that water has been used and fouled, there is sometimes a temptation to discharge it into the nearest river, regardless of consequences.

Thanks to progress in sanitary engineering, aided by biological and chemical discoveries, there is less excuse for inefficient treatment than formerly ; but the multiplicity of industrial wastes admitted into sewers accentuates the problem of what is the best form of treatment.

Land irrigation is a sound and reliable method of purifying sewage, but it is unsuitable for the majority of urban districts.

The percolating filter has taken the place of the contact bed, but its universal popularity is on the wane, chiefly because it tends to give rise to smell and to engender flies in summer.

Bio-aeration or activated sludge treatment now takes first place ; it is devoid of both smell and flies, and is mechanically adaptable to the production of an effluent which meets the requirements of the stream.

Sludge digestion is at last receiving the attention it deserves. It is economical, efficient and final. It produces a valuable non-smelling gas —methane—and yields a humus which is easily dried, containing about 3 per cent. of nitrogen. This method of sludge treatment has come to stay.

Public opinion may have been slow to appreciate the work of the sanitary engineer. Still, it has advanced steadily, and it is evidenced by recent legislation—*e.g.* the Local Government Act, 1929, which contemplates the co-ordination of urban district authorities with the object of reducing the number of sewage purification works. The predominant example of this is found in the county of Middlesex, where one up-to-date plant is being substituted for twenty-nine existing sewage works.

Mr. H. F. ATTER.—*Legal aspect of river pollution, with special reference to the Rivers Pollution Prevention Act*, 1876 (10.10).

The Joint Advisory Committee on River Pollution in 1928 reported that there was no lack of administrative authority for enforcing the law. 'Nevertheless it is admitted on all hands that many of our rivers are seriously polluted and that the law designed to prevent avoidable contamination is to a large extent not put into operation.' This paper examines the provisions of the existing law, more particularly the Rivers Pollution Prevention Act, 1876, and suggests means by which it may be more effectively enforced. The Act deals in separate parts with solid refuse, sewage and trade refuse. It applies to all non-tidal rivers and streams, and the duty of enforcing it is entrusted to County Councils, Borough Councils, Urban and Rural District Councils and Fishery Boards. The procedure is not expensive, as the County Courts have jurisdiction to deal with all offences. The Act also enables local authorities to give facilities to manufacturers to drain their trade effluents into the sewers, and thus enables sewage and trade refuse to be purified at one centre under expert management.

Prof. W. E. ADENEY and Dr. A. G. G. LEONARD.—*Purification of sewage by natural processes* (10.25).

Results of laboratory experiments which elucidate certain fundamental principles involved in the aerobic purification of sewage liquors are given.

By the extraction and analysis of the gases occurring in polluted waters undergoing oxidation it has been possible to study the changes accompanying the destruction of impurities occurring in true and colloidal solution in such waters. Thus it has been established, within the limits of experimental error, that equal volumes of the same polluted water undergoing aerobic fermentation consume equal quantities of oxygen and give rise to products which are constant in quantity, provided always that dissolved oxygen be present in excess.

The rates of solution of oxygen and nitrogen by fresh and salt waters have been determined and a well-defined mathematical equation obtained connecting rate of solution, surface exposed, volume of water, temperature and degree of saturation.

Air dissolved by water at its surface does not remain concentrated in the surface liquid but sinks more or less rapidly, causing aeration to depths of at least 10 ft., a process for which the term 'streaming' has been adopted.

Mr. John Haworth, M.B.E.—*Bio-aeration or activated sludge* (10.40).

Mr. Frank C. Vokes.—*The treatment and utilisation of sludge* (10.55).

Toward the middle of the last century the frequent epidemics, which attacked urban populations, aroused public opinion, and gave rise to the gradual development of pure water supplies, water carriage of the excreta, the removal of the settleable solids from the sewage, and the oxidation of the foul water.

Anticipations of a rich financial return from the general application of the settled solids to the land have not been realised. In many cases it is necessary to dispose of this offensive matter or sludge on site. Its character can be completely altered by subjecting it to a process of digestion.

At the works of the Birmingham Tame and Rea District Drainage Board is treated the sewage from a population of 1,200,000. The watery mass of highly odorous material known as sewage sludge is digested in separate tanks in two stages, pumped on to drying beds, lifted and dumped. There is no nuisance from smell.

The size of the works required for carrying out this process has been materially decreased recently by utilising the gaseous products of the digestion process. The power required for other purposes has been supplied continuously by consuming the sludge gas in engines having a total of 1,000 horse power, the waste heat abstracted from the engine cylinders and from the exhaust gases being used to raise the temperature of the digesting sludge.

The rate at which digestion occurs depends very largely upon temperature, and the provision of means for maintaining the digesting sludge at a uniform temperature enables a sewage works to be independent of any outside source of power.

Mr. H. R. Lupton.—*Machinery for dealing with sewage* (11.10).

The paper is intended primarily as an appendix to those dealing with sewage treatment. It deals only with the mechanical appliances involved, not with constructional and civil works.

The mechanical appliances are divided into four categories according as they deal with (*a*) crude sewage, (*b*) sewage liquor, (*c*) sludge, (*d*) screenings.

Under the first category are described (i) pumps and ejectors, with special reference to unchokeability, (ii) settling tank mechanisms and screening plant.

Under the second category, in addition to (i) pumps, fall (ii) aeration devices, including agitators and surface aeration plant, sprinklers and air-compressors with diffusers, and (iii) dosage apparatus including chlorinators and devices for adding precipitants, etc.

Under the third category fall (i) pumps and ejectors, (ii) stirrers, gas-collectors, heating mechanism, etc., (iii) sludge presses and driers, grease extraction apparatus, etc.

In the fourth category are included (i) conveyors, (ii) disintegrators.

In addition to the above, brief reference is made to special valves, floating arms, etc., which are used in connection with sewage manipulation.

DISCUSSION (11.30).

AFTERNOON.

Visits: (i) to sewage works of Birmingham Tame and Rea Drainage Board.
(ii) to Fort Dunlop.

Tuesday, September 12.

Mr. JOSEPH GOULDBOURN.—*Shoe manufacturing machinery and some special problems in its design* (10.0).

The paper outlines the comprehensive character of the machinery and summarises categories of special machines developed for performing certain important operations of the many different ones into which the manufacture of shoes has become divided. In illustration of peculiar problems which the designer has had to solve, salient features of several machines are discussed. These are a stitching machine, which will set a lockstitch reliably at a selected depth in a sole as much as $\frac{3}{4}$ of an inch thick while sewing 1,000 or more stitches per minute; metallic fastening machines comprising means for marshalling and delivering both headed and headless nails; a pulling over machine pneumatic mechanism for simultaneously inverting and delivering a number of tacks to an equal number of tack driving mechanisms; a lasting machine for securing the upper to the insole by staples which clinch themselves in the thickness itself of the comparatively thin insole; a sole edge burnishing machine in which, while the sole edge is traversing across the tool, both are automatically adjusted to the dual sole curvatures by systems of feelers operating machine controls through hydraulic relays, and, lastly, a pattern grading machine embodying duplex pantograph mechanism.

Prof. MILES WALKER, F.R.S.—*Great engineering works of profit as a cure for unemployment* (11.0).

During the last twenty years many sane engineering projects have been brought forward in different parts of the country—underground railways in large towns, bridges over rivers, extensions of electric power generation and transmission, the change from tramways to Diesel-driven omnibuses, the change from steam-driven locomotives on our main-line railways to Diesel-electric locomotives especially of the type containing torque-conversion apparatus. Projects of these kinds are still before the public. In

many cases the possibility of a large margin of profit can be shown. In many the margin of profit is not sufficiently enticing to stir the people to action. The paper deals with some of the projects which promise a fair return and would keep employed hundreds of thousands of workmen and workwomen.

It also deals with methods of finance similar to those proposed in America; for enabling the people to purchase the things that they have made or for contributing to the cost of the future wealth-producing projects.

Mr. M. Du-Plat-Taylor.—*Sea defences and reclamation of land from the sea* (11.30).

The loss by coastal erosion and the gain of land by accretion around the coasts of Great Britain about balance, but the land lost is generally good agricultural land, and even parts of towns or villages, and the gain is only sand or shingle.

The loss can be prevented by coast defence works, such as sea embankments or sea walls, the drainage of clay cliffs, and groyning. Although reclamation of land from the sea for industrial purposes may be an economic process it is not so for agricultural purposes unless it is carried out in combination with dredging or the disposal of waste materials.

Material deposited on reclamation areas may be material dredged from adjoining navigation channels, which can be pumped ashore by suitable plant. This is often cheaper than sending it out to sea to be dumped in deep water.

House refuse may also be used for raising the level of such low-lying lands if economical means can be found for so depositing it. In London alone, the quantity of house refuse to be disposed of annually is $1\frac{1}{2}$ million tons, and in addition, 3 million tons of sludge from sewage disposal is sent out to be dumped at sea. The Author suggests that means of disposing of all this upon marsh or mud land should be investigated.

As regards coast defence works, various forms of protection will be discussed and approximate costs given; and finally, various schemes for enclosure and reclamation which have already been put forward will be examined from the point of view of probable ultimate profit and the relief of unemployment.

Mr. Walton Maughan, M.I.Struct.E.—*Some canal projects* (12.0).

Afternoon.

Visit to works of British United Shoe Machinery Co. Ltd.

Wednesday, September 13.

Mr. A. M. McKay and Mr. R. N. Arnold.—*The effect of time and temperature on the embrittling of steels* (10.0).

The effect of stress, of temperature of heating, and of time of heating on the embrittlement of steels are considered; brief mention is made of results obtained from tensile and hardness tests. Results of tests showing the embrittlement with time of mild steel after quenching from moderate temperatures are also given; an attempt is made to correlate results and to suggest a possible explanation of embrittling phenomena.

REPORTS OF RESEARCH COMMITTEES (10.45) :—

Earth Pressures.

Electrical Terms and Definitions.

Stresses in Overstrained Materials.

SECTION H.—ANTHROPOLOGY.

Thursday, September 7.

Mr. K. H. JACKSON.—*An aspect of Celtic seasonal literature : the weather prophecy* (10.0).

The primitive mantic tradition in Ireland included prognostications of weather and fertility as well as prophecies relating to human affairs, the two not being separated but treated as general manifestations of prosperity or the reverse, and traces of the same kind are found in Wales ; certain obscure Irish poems are to be explained in this way rather than as charms or descriptions, but the distinction between charm and prophecy is not always easy to draw. Various systems of foretelling the weather other than by direct inspiration, particularly from observations about New Year's Day ; perhaps originally part of the native mantic and seasonal lore, but later much influenced by the Latin learned tradition and disinfected from the taint of paganism by Christian formulæ. Survivals in modern Celtic folklore.

The possibility that weather prophecies influenced seasonal poetry ; similarities of phrasing common to the mantic poems and prose weather-lore are perhaps to be found in some of the Irish poems on the seasons, and also traces of Welsh weather-wisdom in an early Welsh poem on winter.

Prof. Dr. JULIUS POKORNY.—*The origin of the Celts* (10.45).

People usually look for the Celtic cradle to south-west Germany and the Rhineland, where are found the greatest number of Celtic river-names, and where later the historical Celtic La Tène culture originated from the western Hallstatt culture ; in the Bronze Age the so-called Tumulus culture was found there.

Of late it has become evident that at about 1200 B.C., important movements of peoples and cultures had gone to transform the cultural aspect of the greater part of Europe. The people of the Lausitz culture or urnfield civilisation, starting from eastern Germany and western Poland, seem to have conquered great parts of middle and southern Europe, among them the Celtic cradle, where they became finally absorbed by the earlier Tumulus folk. In this way the Celts of history came into existence.

The language of the urnfield people gives us an important clue to the origin of the Celts. The urnfield colonies in Hungary and Upper Italy can be shown to belong to the Illyrians and Venetians, two branches of the western Aryans, and the great number of Veneto-Illyrian place- and river-names in the Lausitz territory point to the same direction. The linguistic isolation of the Teutonic languages (for the relations with Celtic are late) is easily explained by the fact that their southern and eastern frontiers were occupied by Veneto-Illyrian peoples, of whose language, the ancestor of modern Albanian, we know very little.

The Celts must be the product of amalgamation between the Veneto-Illyrians and the Tumulus people, which may be called Proto-Celts. Since the Aryan invaders of Italy, whose language is most closely related to that of the Celts, seem to have come from the same region, the Tumulus people may be identified with the primitive Italo-Celts who had remained in their old home after the Italic peoples had left for the south.

The speaker has been able to show for the first time the close relation between the Veneto-Illyrian and Celtic languages, and has discovered many linguistic traces of the Veneto-Illyrian occupation in Celtic territory. The Aryan elements in the language of the so-called Ligurians are probably due to an Illyrian invasion as well.

Presidential Address by Rt. Hon. Lord Raglan on *What is Tradition?* (11.30). (See p. 145.)

Mrs. H. Wragg Elgee.—*The Earth Mother cult in N.E. Yorkshire* (12.30).

The Earth Mother is found as the Old Wife in our Moorland area, this name being attached to sacred stones, old trackways and burial sites. The Old Wife is the name given to the last sheaf of corn cut at harvest, in our area known as the mell-doll. Another name for the Old Wife is Carlin, of Scandinavian origin. As a spring goddess she is preserved to-day in Carlin Sunday. She was worshipped as Freya and Nanna in the ninth and tenth centuries. We have ample evidence that she was guardian of the dead throughout the Bronze Age, and a double-axe cult derived from Crete pervaded the district. Not only the axe, but shells, necklaces and cup-stones are all sacred symbols of the Earth Mother. She was also worshipped in the Bronze Age as a sky goddess. A hitherto unrecognised type of megalithic monument, groups of three standing stones, represent her in her threefold aspect. We find many traces of her cult to-day, as, for instance, in our inn signs and bee customs.

Afternoon.

Mr. W. Keay.—*The Raw Dykes, Leicester : a Roman aqueduct* (2.15).

On the south side of Leicester, within a mile of the centre of the City, is a grass-grown earthwork known as ' The Raw Dykes,' the use of which has puzzled many generations.

It is constructed on side-long ground, on the ' give and take ' principle, the excavation on the east side being deposited as an embankment on the west side. The channel thus made is 340 ft. long, 20 ft. wide at the bottom, 72 ft. at the top, and averages 10 ft. deep. There is evidence to show that the earthwork (within recent years) extended towards the city for nearly a mile.

Former writers have ascribed its use as ' the bounds of a Roman Cursus or Racecourse,' others to ' Some defence to the Roman Camp.'

The author contends that it is the remains of a Roman aqueduct tapping the river on the upstream side, for the water supply of Leicester (Ratæ), and discharging it on the downstream side.

Mr. A. T. J. Dollar.—*Prehistoric and some historic communities of Lundy, Bristol Channel* (2.45).

The presence on Lundy of undoubted microliths, well-finished round scrapers of Bronze Age type and many manipulated blades of beach-flint

and quartzite which occur in association with lean-to dolmens, standing stones, part of a stone row, stone circles, tumuli and kists indicates that this isolated granite island in the Severn Sea was occupied by at least two prehistoric communities of Cornubian affinity.

Evidence on the island suggests that an early and backward settlement of Neolithic cultural type was absorbed or replaced by a subsequent population of Mesolithic or Early Bronze Age culture.

The earlier community seems to have produced and employed distructive tools, including rostrated round scrapers, deeply notched flakes, limpet-lifters and limpet-hammers.

The later community is to be associated with the more elaborate tools of blue flint, with the stone monuments and the graves. Discoveries of barrel-shaped collared beads and fragments of a gilt-bronze ornament, together with cylindrical and spherical beads of cobalt glass, point to an occupation of Lundy by a Viking or Irish Early Iron Age people. An inscribed monolith bears out the former conclusion.

The island was known to the Romans as Herculea, while it appears as Caer Sidi, the Fortress of the Fairies in Welsh folk-lore. Its recorded history, which begins in the twelfth century, is one of many short occupations by a succession of transient communities, including rebellious French nobles, Scottish sea-raiders, Spanish pirates, Turkish corsairs, English privateers, soldiers, farmers, monks and quarrymen.

Dr. A. Raistrick.—*Developed Tardenoisian sites in N.E. England* (3.15).

Many surface finds of flints of Mesolithic type have been recorded in recent years from the North of England, but only rarely have flint sites been excavated in a position with clear stratigraphy, until the work of Buckley and Armstrong. This paper records several sites from the north-east coast, which occur on the boulder clay and are covered by the coastal sand-dune belt, and several sites from the Pennines where peat (dated by pollen analysis methods) is the cover. Some of the coastal sites are very rich and have yielded a few thousand flint chips and implements, sufficient to warrant a statistical summary of the culture. The main types of worked flint are very beautiful elongated cores and core scrapers, small circular scrapers, blades with secondary microlithic chipping, and geometric and semi-geometric ' pygmy ' points. The culture shows local development from early Tardenoisian, and is occasionally associated with finely chipped arrow points and early types of Neolithic implements. The relation of the sites to the sand-dunes and coastal ' forest-bed ' peats has been investigated, as well as the age of the peat cover of the Pennine sites.

Dr. F. Oswald.—*Margidunum, a Claudian camp on the Fosse Way* (3.35).

Mr. Bertram Thomas, O.B.E.—*The first crossing of the South Arabian Desert* (5.30).

Friday, September 8.

Prof. C. Daryll Forde.—*Native warfare on the Lower Colorado River* (10.0).

The tribes of the Lower Colorado River are remarkable for their cultural divergence from immediately surrounding peoples. They are not transitional between the Pueblo peoples to the east and the Central Californians to the west and appear to have been uninfluenced by the westward infiltration

of Puebloan concepts, although there is evidence that some of these reached the Pacific coast. One of their outstanding characters is the existence of strong tribal sense and its association with warfare. These features are lacking among the peoples of adjacent areas. An analysis of the military conventions and insignia of the Lower Colorado peoples suggests unexpected parallels with the Western Plains area beyond the Rockies. This relation is, however, not to be explained by a late westward diffusion of Plains concepts, but rather to a common basis of military tradition, probably of southern origin. No elaboration of military societies has occurred in the Lower Colorado region, but the belief that military success is essential to the well-being of the tribe and that warfare should be conducted by formal challenge and set battle has led to prolonged hostility between traditional enemies within the area.

No economic objective or territorial aggrandisement is sought in warfare. Militarism is maintained and perpetuated by magical beliefs and by the social prestige of bravery as exhibited in conventional forms and obligations.

Prof. V. Suk.—*The Eskimos of Labrador and the extinction of primitive races of man* (10.30).

The latitude of the Labrador peninsula is about the same as that of England, and Cape Chidley in the north corresponds with the North Cape of Scotland. Yet, owing to the North Pole currents, the whole region has more or less the character of an arctic country. Its aboriginal inhabitants were Eskimos, yet, at present, there are beside 800 pure blood Eskimos many mixed breeds, White and Eskimo, and White settlers as well. There is no doubt left that the pure blood Eskimos of Labrador, who two centuries ago inhabited also the South Coast, and at present are restricted to the North Coast, are slowly dying out. It is the same with the Alaskan Eskimos, and not only Eskimos, but many of the more isolated small groups of mankind are dying out. It is certain that the Labrador Eskimos were, for the last hundred and fifty years, fortunate enough to be under a very conscientious and peaceful administration, yet, in spite of that, their numbers are diminishing. For comparison we may consider the fate of the Australian aborigines, and a close study of both groups indicates that the main causes show the same features. So, taken altogether, the history of primitive groups of mankind, the downward trend of their vitality and consequent extinction may be summarised as follows : (1) Extinction by weapon, in the same sense as many animals have been exterminated. This is, of course, now out of question and only of historical interest, for, in fact, all over the world we see the working of humanitarian bodies, as, for instance, Native Health Service, Mission Societies, etc. (2) Extinction by sudden changing of the respective milieu. (3) Extinction by imported disease. (4) Extinction by destruction of the natural resources necessary for the aboriginal mode of life. (5) Extinction by mixing. The items under Nos. 2, 3, and 4 we may include under one heading as ' Effects of Europeanisation,' and these, under the modern aspects of general pathology and teachings on nutrition and morbidity, are of greatest importance—in fact, Europeanisation is at present almost the only factor to be taken into consideration.

This paper is based on personal observations among the Eskimos of Labrador, on Dr. Hutton's study of health conditions among the Eskimos of Labrador, on the studies of the health status of Australian Natives by Prof. Burton Cleland, on the study of the health status of different African tribes by Orr and Gilk and on the works of R. McCarrison, Coonoor, South India, on nutrition and disease.

Dr. L. S. B. Leakey.—*Kikuyu marriage customs and problems arising therefrom as a result of contact with European civilisation* (11.0).

Mr. James Hornell.—*Indonesian contact with East African culture* (11.30).

Indian contact with Sumatra and Java, commencing before the opening of our era, gave rise to a rich civilisation, coupled with much maritime activity and the construction of large sea-going vessels with double-outriggers. Voyaging in these, Sumatrans formed settlements in Madagascar about the second to fourth centuries A.D. The voyages were probably coastwise, with calls at Ceylon, Malabar, and the East African coast. Other settlements were made in the tenth century or possibly rather later. African slaves formed part of the tribute sent to China from Sumatra and Java and an Arab writer mentions a slaving expedition from Indonesia in the tenth century.

The Bantu strain in Madagascar is probably the result of the importation of African slaves by the Indonesian colonists.

Technological evidence also points to intimate contact. The presence of the coconut palm, the coconut scraper, the bar-zither and the double-outrigger canoe in East Africa is strong evidence of long-continued Indonesian influence radiating from coastal settlements. Arab writers mention Sumatran and Malagasy voyages to Kilwa and Mogadishu, and one records a definite tradition of the occupation of Aden by Malagasy people. Their influence has penetrated inland by diffusion ; the Baganda canoe incorporates features of Javanese vessels, the bar-zither has penetrated to Lake Tanganyika and some of the beads in Rhodesian ruins have Indonesian counterparts.

Dr. M. Fortes.—*Some aspects of kinship and the family in West Africa* (12.0).

An area in the northern territories of the Gold Coast has been selected, and the structure and functions of the family investigated. The type of family found is common in many parts of West Africa. It is a joint family, acting as a unit in most departments of cultural life, under the control of a patriarchal head. While the type is constant, many variations occur. It is proposed to investigate, on the one hand, the factors which make for the *internal cohesion* of this type of family grouping, and, on the other, how its cohesion with the greater society is preserved.

Dr. Lucy Mair.—*The growth of economic individualism among African peoples* (12.30).

The essential difference between native and European economic organisation lies, not in some form of communism, but in the fact that in the native system the mechanism of distribution did not consist in a series of exchanges of goods with a view to profit, but was closely correlated with the whole political system. Wealth was the privilege of political authority, and was acquired not by economic skill or effort but by the exercise of qualities approved by those in authority, especially wisdom in council and courage in war, and the desire for it was thus a motive for socially approved behaviour. Wealth carried with it the obligation of generosity to relatives or subjects, and one reason why it was sought was because it enabled the possessor to make the gifts required by custom on a more lavish scale than his neighbours. This

system worked satisfactorily, largely because native wealth consisted in a limited range of commodities in which the point of satiety was reached fairly early.

The introduction of European economic methods has profoundly modified such systems. Wealth is now the direct result of individual economic effort, and the opportunities of acquiring what he desires by wage-labour make the individual independent of paternal as of political authority. Economic privileges begin to be abused when there is so much to be gained by disregarding the obligations that go with them. Thus the economic progress of Africa is tending to be a cause of serious social disintegration.

Afternoon.

Mr. A. F. Dufton.—*Inheritance of acquired characters* (2.15).

The fact that many eminent men were begotten by fathers of ripe age suggests that capability may be in some degree an acquired character and that the older the father the greater the chance of it being acquired. The striking difference between the frequency distributions of the paternal ages of one thousand eminent men and those of a more normal population supports this view.

The reason is discussed why, when the inheritance of other acquired characters is barely perceptible, the inheritance of a development of the brain should be comparatively striking. Further evidence is adduced in support of the thesis. The question as to whether acquired characters are inherited is considered to be not merely of academic interest but, so far as man is concerned, one of paramount importance. The eugenic implications are briefly discussed.

Prof. R. Ruggles Gates, F.R.S.—*The blood groups as an index of racial characteristics* (2.45).

It is now generally agreed that the A and B blood groups are inherited as dominant Mendelian units, and that the factors A, B and O are multiple allelomorphs. The A and B blood groups appear to have arisen as repeated mutations from O. A and O only are present in such primitive or outlying peoples as the Australian aborigines, Bushmen, Lapps and Polynesians. On this and other evidence A is regarded as older than B. It has probably spread, (*a*) by repeated mutations, (*b*) by inheritance, (*c*) by migration of peoples. B, which is highest in Eastern and Southern Asia, where A is also present, probably spread later from an Asiatic centre.

The Eskimos and American Indians, when pure-blooded, are probably all O. This is difficult to account for, as they are relatively advanced and Mongoloid, and might therefore have been expected to have received both A and B before crossing Behring Strait. Tests of 300 coastal Indians of British Columbia show that they also probably had originally no B nor A, and are thus in agreement with other American Indians. The blood groups also throw further light on infiltration and race mixture in the case of Australian aborigines, Bushmen, Maoris and Indians.

Dr. Harry Campbell.—*The factors which have determined man's evolution from a primitive primate* (3.15).

The evolution of man from a Primitive Primate has essentially been an evolution of brain. A study of this evolutional phase brings into prominence certain evolutional factors : (1) The apparent potency of natural selection

as compared with the transmission of acquired characters: seeing that cerebral neurons do not multiply after birth, phylogenetic cerebral increase must have been due to the selection of innate cerebral variations. (2) The stimulating influence of competitive social life. (3) The possession of exquisitely prehensile hands conferring survival value on super-average intelligence. (4) The scope factor, which widened out from the arboreal to the semi-terrestrial life, and from this to the wholly terrestrial life. (5) A hunting career, which, in the case of the proto-human (who lacked the equipment, anatomical and instinctive, of the carnivore), caused success in the hunt to depend largely upon the possession of a nimble intelligence, thus enhancing the survival value of super-average intelligence. (6) The influence of polygamy: the bravest and most intelligent leaders secured the largest number of mates, and thus left the most numerous progeny. (7) Inter-tribal warfare, which led to the elimination of the least intelligent groups.

Mr. A. L. ARMSTRONG.—*Summary of recent and current excavations at Creswell Crags* (3.45).

Dr. E. H. HUNT.—*The Rafai fakirs of Hyderabad* (5.30).

Saturday, September 9.

Excursion to Creswell Crags, Derbyshire; Southwell Minster; Newark Castle; Margidunum (in the Fosse Way).

Sunday, September 10.

AFTERNOON.

Excursion to earthworks in East Leicestershire; Burrough Camp; Sauvey Castle, and Castle Hill Camp, near Hallaton.

Monday, September 11.

Mr. A. W. CARDINALL.—*The strengthening of superstitious beliefs among the tribes of the Gold Coast* (10.0).

It is commonly agreed that contact with Europeans has been to a considerable extent destructive of African social, political and religious institutions. This is only partly true; actually in certain spheres the reverse has been the case.

The most prominent features of religion as observed in the Gold Coast are sumanism, nature-gods and witchcraft. Complementary to these are the observance of omens and a deeply ingrained belief in luck.

In these European contact tends to increase superstition through example, inquiry, acquiescence and even belief therein by individuals. Authority has been forced on many occasions to recognise and support beliefs that were dying out; and in the case of witchcraft European Administrations have been placed in the dilemma either of recognising it in order to prohibit its practice or of strengthening its power by forbidding measures taken by the indigenes against its machinations.

The numbing effect of omen-taking, consultations with soothsayers and similar practices has not hitherto received the attention it deserves. Most Gold Coast natives will do nothing without observing the ritual of the omen. Thus he naturally tends to become more and more engulfed in the ruts of custom. The introduction of new ideas by Europeans has increased the opportunities and broadened the outlook of the native, and thereby enlarged immensely the field and scope of this practice.

Finally the attribute of luck given to one who has power or success has been inevitably attached to the European. This has resulted in magnificent loyalty, which in turn has ensured success and therefore confirmed the belief.

Dr. R. S. Rattray, C.B.E.—*Present tendencies of African Colonial Governments* (10.40).

The British system of governing her Colonial possessions in Africa may be conveniently summed up in the phrase '*Indirect Rule*.' By this is implied, (*a*) the administration of the African masses by or through Africans on lines conforming to their own national customs and traditions, and (*b*) that the European is only there to guide, with a minimum of interference, being prepared eventually to quit, leaving the African 'to stand alone.'

A certain long-standing self-complacency, regarding this system—arising, perhaps, from the fact that all lovers of Africa and her people desire to see the African national genius preserved, and because 'Indirect Rule' seems the only way of attaining this end—has begun to give place, in the minds of some of its staunchest adherents, to genuine doubts and grave anxiety. It seems certain that the system will very soon have to withstand onslaughts both from within and from without. The assault from the inside will come from the masses of the people themselves, who are likely to become estranged owing to the undoubted tendency of 'Indirect Rule,' as now applied, to build up centralised African autocracies, disregarding the bases of former African constitutions and states, which were decentralised and democratic. The attack from the outside will be delivered by that ever-growing educated African element who feel aggrieved, because they sometimes appear to be excluded by a system where Western education and Western lines of progress seem at a discount.

Were neither of these dangers ever to materialise, there would yet be a third. Does 'Indirect Rule' mean that we are to build up states, which, while perhaps being Arcadian for the anthropologist, and possibly a model for barbaric or mediæval sovereignties, would nevertheless be greatly handicapped were their sheltered privacy to be rudely invaded, and were they suddenly called upon to stand alone and unprotected amid the rough forces of the ever-changing world around them ?

I believe I am voicing the opinion of the majority of educated Africans when I state that 'Indirect Rule' and 'Anthropology' are both regarded by them as veiled attempts at 'keeping the Africans in their place.' Yet, without their co-operation, the whole structure of 'Indirect Rule' and any permanent value accruing from anthropological research must surely crumble. These and other questions are briefly discussed.

Sir Richmond Palmer, K.C.M.G.—*Stone circles in the Gambia Valley* (11.25).

(1) A short survey of the ethnic factors present in the Western Sahara and Sudan in the period A.D. 600–1400, distinguishing between the stocks known as Sarakolle, Jolof, Tuculor, Sereres, Mandinka, etc., the primitive Saharan stock known as Nemadi.

The Nemadi, it is believed, represent the peoples who, as far back as can be ascertained, were the original Wangara—i.e. Hamite or Kushite nomads and hunters, 'people of a place' or, perhaps, 'cave.' It was intermarriage between the Nemadi and the darker races round them which produced the negroid Wangara or Wakori who were the subjects of the early kings of Gana.

The term Wangara continued to be applied to the Mandinka negroids after they invaded from the south the region called Aukar or Wagadu about A.D. 1200.

The Nemadi, the Sereres, and possibly after A.D. 1200 Jula-speaking Mandinkas, represent the Wangara or Gangari stock which fused with nomad Fulbe Barbars in Hodh and Aukar about A.D. 900–1000, produced the so-called Tucolor or Takrur, commonly called Fulahs or Fulani, and Taurud by Sultan Muhammad Bello of Sokoto.

The Sarakolle, on the other hand, are the descendants of mixed marriages between aliens of Jewish or, at least, Syrian origin, who towards the middle of the first millennium A.D., by peaceful penetration, developed the 'gold trade' with Bambuk from Morocco and Gana, and Sus.

(2) The 'Stone Circles' of the Gambia and Sine in Senegal are described, and their probable connection with the mode of burial practised by the Sarakolle kings of Gana is shown—a mode of burial which must have been common to many Barbar or half-Barbar tribes extending across the Sudan to Bornu and Borku in the period A.D. 600–1000.

In so far as burials are concerned, the interior of the circles presents the same features as those excavated at El Walaji near Timbuctu, at Katsina, and in Bornu.

The question arises, why were these burial mounds surrounded with menhirs, and how is it that the stone-work of these menhirs is so good?

The answer to the first question is that the menhirs correspond to the stockade of a town or compound; to the second, that the stone-work must have been due indirectly to guilds of Jewish and Syrian stone-masons who flourished at Sijilmessa in the eleventh century, as also at Kumbi, the Gana capital.

The geographical distribution of the circles, as well as other considerations, show that they were erected at a period when the influence of Gana extended to the Gambia River, before the rise of the Malinki towards A.D. 1200, and thus that traditions enshrined in the fourteenth-century maps concerning the 'Nile of Gana' should be interpreted as referring to the towns which created these stone circles, and the 'Gambia River' as being the principal mouth of the 'Nile of Gana.'

Dr. J. H. Hutton, C.I.E.—*Megalithic work in Assam* (12.10).

Afternoon.

Mr. E. G. Bowen.—*Hill forts and valleyward movements of population in Wales* (2.15).

A classification of the chief early earthworks of the Principality indicates the importance of the following types: the contour camp, the promontory fort, the rectangular earthwork and the motte-and-bailey castle. These groups cover a wide range in time, and a detailed examination of the earthworks of the county of Carmarthen shows that each has a distinct altitudinal province. The average altitude of the contour camps is about 600 ft., the promontory forts about 430 ft., the rectangular earthworks about 250 ft.,

while that of the motte-and-bailey castles is about 180–190 ft. With the exception of the promontory forts whose general altitude depends on physiographical factors, it is suggested that this altitudinal sequence illustrates changes in human economy over the period represented by the age of the earthworks concerned. The contour camps, together with a large number of the promontory forts, occur beyond the highest level of early cultivation, and their occupants were interested mainly in mountain pastures. Earthworks of rectangular form, situated mainly on the lower hill-slopes, suggest that their occupants had but an intermittent interest in the upland pastures, which they visited perhaps only during the summer season. The location of the motte-and-bailey castles illustrates that the homes of the newcomers were definitely in the valley bottoms, associated with an arable as opposed to a pastoral economy. Though the conquest of the once densely forested valleys was complete by this time, interest in the uplands continued, as is shown, by the survival of seasonal transhumance in Wales throughout the Middle Ages, and even into our own time.

This survey has been undertaken for the forthcoming *History of Carmarthenshire*, and will form part of a section which is being prepared in collaboration with Dr. Cyril Fox.

Mr. R. U. Sayce.—*The distribution of the belief in fairies* (2.45).

Prof. W. W. Jervis and Mr. S. J. Jones.—*The village of Congresbury, Somerset : a study in land tenure* (3.15).

Congresbury is situated 12 miles south-west of Bristol on the main Bristol-Weston road. It has particular interest for the student of land tenure because in two of its common meads—the East and West Dolmoors—a curious method of annual land allocation persisted until the local enclosure Act of 1811. The redistribution took place on the Saturday before Old-Midsummer. Each man having a claim to land in the Dolmoors had a distinctive mark which was cut on a number of apples equal to the number of strips to which he was entitled. As each acre was measured, with a chain the length of which had been checked along the central aisle of Puxton Church, one of these apples would be drawn from a basket by a small boy. The mark on it would be cut in the turf, and thus the ownership of the acre for the ensuing twelve months would be decided. The main objects of this paper are to study the manner in which these holders settled jointly questions concerning these common meads, and to make a contribution towards the solution of the problem of this curious survival. The data presented is derived mainly from surveys and from the accounts of the Overseers of the Dolmoors, the latter covering the period 1685–1766. It is shown that the Dolmoors were comparatively poor land which continued to be allotted annually at a time when most of the better land had been enclosed. The customs noted in connection with them probably once operated over the whole of the village land. The Dolmoors are, in fact, remnants of the common meads around which have persisted ancient customs, the origin of which cannot yet be definitely determined.

Dr. Cyril Fox.—*The colonisation of Britain with special reference to the Midlands* (5.30).

The geographical relation of Britain to the Continent is perhaps more familiar than its structural character ; both aspects are found to be of primary importance in the study of the colonisation of the island from

Neolithic times onwards. Broadly speaking, Britain south of the Forth-Clyde isthmus consists of two parts, the Highland Zone to the west, and the Lowland Zone to the east.

The structure and soil-character of Lowland Britain explain in large measure the distribution of the population in this, the most important half of the country, in early times. The chalk formation forms the main framework. To the west and north-west of this complex lie the limestone ridges of the Mendips and the Cotswolds ; an extension of the latter (the Jurassic outcrop) leads by way of Lincoln Edge to the Humber, beyond which is a habitable outlier of chalk—the Yorkshire Wolds. Waterways such as the Thames, the Fen rivers and the Trent provide easy access for invader or trader to every part of the Lowland Zone.

The chalk and limestone downlands, gravel terraces by the rivers, and sandy heaths as in East Anglia, provide the settlement areas most sought after by early man ; he shunned the claylands, the gradual utilisation of which is the story of civilisation as expressed in geographical distribution. The large extent of clay in the Midlands hindered the occupation and development of this area of Lowland Britain.

EVENING.

A folk dance exhibition by a traditional team from Great Easton, Leicestershire, and others, with local folk songs. Introductory remarks by Mr. ERIC SWIFT (8.0).

Tuesday, September 12.

Mr. OLIVER DAVIES.—*Sotiel Coronada : an illustration of Roman mining technique* (10.0).

The paper describes the remains of Roman mining and metallurgy at Sotiel Coronada and Sta. Rosa in south-west Spain on the Odiel. At Sotiel there were two periods of working, one by a Roman capitalist about the first century B.C., and the other probably by a government official trained at Rio Tinto of a rather later date. The latter worked to rule, though his knowledge was limited ; interesting evidence is to be found as to Roman methods of prospecting and surveying, the sections of their shafts, and their pairs of shafts. In the second period an iron tool was used, probably a gad ; in the first, it is likely that the rilled stone hammer was still common, and indeed this tool almost certainly continues until Roman times. Finally some remarks are made about a metallurgical establishment exposed at Sta. Rosa ; both liquation and cupellation seem to have been practised here, and there were found a smelting furnace and what appear to be cupels.

Miss D. A. E. GARROD.—*Excavation of the Mugharet el-Tabun, Mount Carmel* (10.30).

Mr. T. BURTON BROWN.—*The Transition from the Neolithic Period to the Bronze Age of Western Asia* (11.0).

Prof. V. GORDON CHILDE.—*Notes on some painted potteries from India and East Iran* (11.30).

Corresponding to the uniform geographical area of alluvial cultivation dependent on a single river system and the advanced urban civilisation

developed under these conditions, the painted pottery of the Indus civilisation from Amri on the lower Indus at least as far as Harappa on the Ravi 500 miles away is astonishingly uniform and at the same time highly sophisticated. Its individuality is expressed in a self-conscious style the distinguishing peculiarity of which is the free use of repetition motives (i.e. motives which can be repeated indefinitely in any direction). Though doubtless inspired by textile models, this style finds so far no parallels in the third millennium or earlier except perhaps in Crete.

Baluchistan and Waziristan, broken up into a number of discrete valleys, did not become the scene of a higher civilisation, but exhibit a variety of barbaric ceramic groups. Both the black-and-red-on-red wares, commonest in Waziristan and the black-and-red-on-buff or cream, commoner in Baluchistan and absent from the Zhob valley, seem closely allied one to another and to the Indus ware both technically and in the motives employed.

Shahi-tump (funerary) ware is closely allied to that of Susa I both in forms and in specialised motives, notably the ' Maltese square ' decorating the centres of dishes at both sites (and also at Samarra). Sherds could be found illustrating the transition from the prevailing grey tint to a pink ; in Sistan the same transition is illustrated as well as that to a green tint indistinguishable from that so common on al'Ubaid and Samarra wares. The connection in the pot-fabrics is confirmed by other graves goods—lapis lazuli beads, alabaster vases, stamp seals, axes of copper—common to Shahi-tump and Susa I. The Shahi graves indeed reveal an extension eastward of Frankfort's ' Highland culture ' in a very pure form and precisely that represented at Susa itself. Yet these graves cannot be earlier than the third millennium and must be later than or partly contemporary with the Indus culture. They therefore demonstrate the direction of the spread of the Highland culture eastwards, not *vice versa*—but afford no clue as to the sources of the common elements in the Indus and Sumerian ceramic traditions.

The pottery from Nal and Nundara in Baluchistan is more sophisticated and shows a deliberate style. The designs are outlined in black on a pale slip and filled in with plum red and sometimes other colours. This fabric, though in time probably contemporary with the Indus black-on-red wares, might be regarded as a development of the black-and-red-on-pale-slip ware from Amri in Lower Sindh which is older than the classical Indus ware. Amri ware in its turn has technical and stylistic affinities to the Jemdet Nasr ware of Mesopotamia, while, on the other hand, some designs foreshadow the typical Indus system of repetition motives.

Dr. C. L. Woolley.—*Ur : the archaic period* (12.10).

AFTERNOON.

Dr. L. S. B. Leakey.—*Excavations at Apis Rock, Tanganyika Territory* (2.15).

Mr. G. Kingsley Roth.—*The decaying arts and crafts of Fiji* (3.0).

Since the advent of European and other civilisations to Fiji which began over a hundred years ago the practice of the arts and crafts of the indigenous population has progressively decreased and processes have changed. The manufacture of bark-cloth and of pottery may be instanced as examples of arts which in some districts are quite obsolete or in others have been

considerably modified by the use of foreign tools or vessels. Such use of introduced implements has in itself caused a number of ancillary occupations to be forgotten. Similarly the means adopted for personal enhancement are now largely those used by Europeans : clothing has replaced the use of oil and native-made ornaments are now rare and becoming rarer because no longer made. The Kava ceremony is an example of a custom which has stood the test of pressure from extraneous influences, only, however, because it is a ceremony essential to many social occasions. Tatuing is not now practised, but the processes have not yet been fully described. The old men to whom one naturally turns for information are passing out and with them is being lost the possibility of recording customs hitherto unrecorded, for the younger generation take little interest in the practices of their forefathers.

Wednesday, September 13.

Prof. E. E. Evans-Pritchard.—*The nature of bride-wealth among the Azande* (10.0).

Dr. A. N. Tucker.—*Primitive music in the Southern Sudan, with illustrations on native instruments* (10.40).

This paper is concerned only with the pagan tribes of the upper reaches of the Nile, not with Arabs.

Music plays a great part in the life of these people, and has many aspects. A very tentative analysis of Nilotic music is here given, obtained from studying their songs and illustrated with some of their musical instruments.

Nilotic scale.—Fundamentally pentatonic, but difficult for us to ascertain which note may be regarded as the ' key ' note in any song. Certain notes in any song seem to vary, within half a tone, according to the mood of the singer, which have a profound influence on our interpretation of the song. These the author calls the ' uncertain ' notes.

This fluctuating pentatonic scale is illustrated on flutes from the Acholi country, which give a reliable scale (since their intervals cannot be altered by any ' tuning ' ; in other instruments, one has to rely on a conception of native tuning).

Rhythm.—This aspect of African music is by far the harder for Europeans to grasp. In playing the instruments here, the rhythm is relatively steady, and is often marked by tapping the instrument or the ground. The main rhythms are 4/4, 3/4 and a fast 6/8. Drum rhythms, which are the most complicated, are not dealt with here.

Types of instruments.—Flute, horn, harp, lyre, sanza, and their distribution in the Southern Sudan, and their probable origin. Songs to illustrate their use.

Dr. S. F. Nadel.—*Anthropological aspects of musical research, with illustrations by gramophone records* (11.25).

This paper demonstrates the rôle which the study of primitive music can play in anthropological research. Central phenomenon of human life as it is, music becomes a paradigm of that complex interrelation and intersection of the different scientific aspects which is so characteristic for anthropological method. The study of music in primitive society can even claim to open to anthropology new ways of approach to some of these aspects. Four

main aspects are dealt with in detail, and are illustrated on gramophone records of primitive music.

(1) The *sociological* aspect. Music as general enjoyment and as social privilege in primitive society. Professional musicians. Music as a central factor in religious ceremony.

(2) The *psychological* aspect. General laws established by the psychology of sound can explain certain widespread characteristics in primitive music. Thus the fluctuation of intervals can be derived from psycho-physiological factors, or the development of a certain primitive polyphony (the so-called 'Parallel-Organum') appears to be due to the elementary psycho-physiological phenomenon of the 'similarity of tones.'

(3) The aspect of *historical connection*. Historical relations, borrowing and diffusion, have to account, in certain cases, for corresponding musical styles in different areas, thus checking very often the psychological aspect (e.g. the 'historical' explanation of the Parallel-Organum suggested for certain areas). Musical instruments become here specially important. Built on principles of physics, and bound up with measures, they offer most accurate and objective criteria for establishing cultural relations (e.g. the ethnology of the African 'marimba').

(4) The *racial* (*biological*) aspect appears to be tangible through music—i.e. through certain musical characteristics which are deeply rooted in biological factors (e.g. the motoric type of man). It is tried to illustrate this as yet very tentative approach on the melodic motion-type characteristic for the songs of two racial groups: the American Indian and the Austronesian.

SECTION I.—PHYSIOLOGY.

Thursday, September 7.

Dr. F. W. Edridge-Green, C.B.E.—*A criticism of Roaf's theory of colour vision* (10.0).

Whilst Roaf's work on colour vision and very fair criticisms of the work of others deserve great praise, his theory presents the same difficulties as any form of the trichromatic theory. There is no evidence of any trichromatic light perceiving apparatus in the human retina. Houstoun has shown that the trichromatic theory is mathematically untenable. The chief objection to it, however, is that like every other theory but mine, it will not explain colour-blindness, particularly those facts predicted by my theory. How, for instance, can the fact that 50 per cent. of the dangerously colour-blind pass the wool test be explained, or that 90 per cent. of the dangerously colour-blind agree with the normal white equation, though they may make an anomalous white equation?

A dichromic or trichromic makes mistakes through defective discrimination and not through the defect of a light perceiving substance when there is no shortening of the spectrum or defect in light perception. A man with shortening of the red end of the spectrum may recognise a very feeble red of shorter wave-length, so this condition cannot be due to a defect in a light perceiving substance which is affected by all rays of the spectrum.

Joint Discussion with Section J (Psychology, *q.v.*) on *Disorientation and vertigo* (10.30).

AFTERNOON.

Visit to Messrs. Boots, Nottingham.

Friday, September 8.

DISCUSSION on *Ossification* (10.0) :—

Prof. R. ROBISON, F.R.S.

The development of the calcified animal skeleton may proceed by two routes, one leading primarily to calcified cartilage, the other directly to bone. Though histologically distinct these processes manifest the closest biochemical relationship. Hypertrophying cartilage cells and osteoblasts both synthesise phosphatase ; and both, at a certain stage in their development, secrete in the intercellular spaces a highly specialised ground-substance possessing properties distinct from those of the enzyme but also essential for normal calcification. In the animal the actual deposition of calcium salt may lag somewhat behind the formation of this specialised matrix ; but the presence and extent of the latter may be demonstrated by calcification *in vitro*. Thus it is found that in embryonic rabbit femora and tibiæ the hypertrophic cartilage is fully calcifiable, possessing both phosphatase and the second essential mechanism (Niven and Robison). In the rudimentary long bones of fowl embryos, however, the cartilage hypertrophies and synthesises phosphatase but does not at once become calcifiable. The full calcifying mechanisms are subsequently developed in parts of the cartilage, but part becomes eroded without acquiring these powers (Fell and Robison). Similar stages in the development of the calcifying mechanisms were noted in cultures of endosteal bone, grown *in vitro*. The area of calcifiable tissue was sharply defined and did not include the whole of the osteoid (Fell and Robison).

Other experimental work (Rosenheim and Robison) has thrown further light on the phosphatase and second calcifying mechanisms, but has not yet provided an explanation of the latter. The calcification *in vitro* of other tissues, such as kidney and aorta, has also been effected by prolonged immersion in calcifying solutions (Rosenheim and Robison) ; but these experiments have emphasised yet more strongly the special properties exhibited by the fully developed hypertrophic cartilage and osteoid tissue.

Dr. HONOR B. FELL.

The classical conception of the osteoblast as a specific bone-forming cell has recently been much questioned. It is sometimes held that osteoblasts and fibroblasts are identical and that ossification is caused by the presence of excess calcium in a young and highly vascular connective tissue. This view is not supported by experiments *in vitro*, in which osteoblasts from the embryonic fowl mandible and from the periosteum and endosteum of the developing limb-bones, when isolated from the body and cultivated under standard environmental conditions, readily form bone *in vitro*, whilst similar cultures of connective tissue growing under the same conditions do not ossify. These results imply that the osteoblast possesses inherent bone-forming properties which are lacking in the ordinary unmodified fibroblast.

A close histogenetic relationship exists between the osteoblast and the hypertrophic chondroblast, and tissue culture experiments have shown that the one type of cell can be directly transformed into the other.

Dr. H. D. Kay.

The work of Robison and his collaborators has shown clearly the importance of phosphatase in the deposition of bone salts, and has incidentally called attention to the fact, apparently forgotten for many years, that phosphorification as well as calcification takes place in growing bone. The phosphatase mechanism is also probably concerned with bone resorption; *in vitro* experiments have shown that under certain conditions bone salts can be transformed again into soluble phosphoric esters in the presence of phosphatase.

Changes in the phosphoric ester content of the tissues in experimentally induced abnormal bony conditions have been observed. The marked increase in phosphatase content of the blood, which is frequently associated with diseases involving the skeleton, has been shown to be reversible after adequate therapeutic measures have been taken.

The production of experimental rickets in rats, on a normal diet containing vitamin D, by adding small quantities of beryllium carbonate to the diet has enabled evidence to be brought forward in support of the view that one of the major activities of vitamin D is to stimulate the uptake of phosphate through the intestinal wall.

Dr. Leslie J. Harris. *Vitamin action and bone formation.*

The following theory of the mode of action of vitamin D explains the known facts and has enabled predictions to be made which were subsequently verified: vitamin D acts primarily by raising the blood Ca × P, causing increased absorption of Ca and/or P from the gut and diminished excretion into the gut (i.e. increased 'net absorption'); the increased calcification in the bone is secondary to the blood change. It has been shown that this theory accounts for the following known facts:—

(1) The association of rickets with high fæcal and (2) low blood Ca and/or P and (3) low bone Ca and P;
(4) The rectification of these errors with vitamin D, (5) the rise in blood Ca × P *preceding the new calcification*;
(6) The influence of the dietary acid-base balance; (7) dietary Ca-P ratio; (8) Be, etc.
(9) Differences in species susceptibility.
(10) Calcification *in vitro* (proportional to Ca × P).

The writer predicted from this theory that overdoses should cause hypercalcæmia and/or hyperphosphatæmia, and hence excessive calcification, e.g. at growing end of bone. These effects were duly found and have since been confirmed by others, the bones and teeth in hypervitaminosis showing highly characteristic abnormalities. (With maximal overdoses and insufficient Ca and P available in the gut, some of the extra Ca and P may be drawn from parts of the bony store.)

The widely advocated theory that vitamin D acts by stimulating the parathyroid has been disproved by showing that the latter, in contrast with vitamin D, does not increase 'net absorption,' and acts by withdrawing Ca from bone, causing loss to the body.

The primary effect of vitamin C deficiency is to cause degeneration of osteoblasts, odontoblasts, ameloblasts, etc.; hence cessation of osteogenesis. Other effects in the hard tissues are secondary.

Dr. Donald Hunter.

The clinical worker is in a position to study ossification in patients under treatment. Progress is followed by estimations of the blood chemistry and

calcium balance, together with histological sections of bone and radiograms taken by controlled methods. In rickets and osteomalacia, vitamin D restores the blood chemistry and radiogram picture to normal. Investigations suggest that the theory of halisteresis is erroneous, and that the action of vitamin D is to calcify osteoid seams.

Clinical, biochemical, radiographic and histological evidence exists that two hormones influence the metabolism of bone. The parathyroid hormone raises the serum calcium, depresses the plasma phosphorus, and causes excessive excretion of calcium in the urine. The thyroid hormone raises the excretion of calcium in both urine and fæces, but there is no increase in the serum calcium. Calcium is removed from the skeleton both in hyperparathyroidism and in hyperthyroidism, and in both the mechanism of removal is a lacunar resorption by osteoclasts.

PRESIDENTIAL ADDRESS by Prof. E. D. ADRIAN, F.R.S., on *The activity of nerve cells* (12.0). (See p. 163.)

AFTERNOON.

Col. C. J. BOND, C.M.G.—*Some recent observations on certain phases of leucocytic and erythrocytic activity* (illustrated with the projection microscope) (2.0).

(1) Incubated leucocyte films showing—
 (*a*) active, (*b*) resting, (*c*) reactivated cells.
(2) Endothelial cells. Ditto.
 (*a*) resting cells ; (*b*) active cells ; (*c*) phagocytosed red cells.
(3) Phagocytosis of pigment particles in active, resting and reactivated cells.
(4) Leucocytes and dendrites (3).
(5) Living pus cells.
 (*a*) active, (*b*) resting.
(6) Washed red cells, showing passage from disc, through prickled, to the spheroidal shape.
(7) Restoration to disc form by addition of blood serum or soap (sodium oleate).
(8) Auto (pseudo) compared with group agglutination.
(9) Effect of reagents on intracellular hæmoglobin.
(10) Avian, amphibian and fishes' red cells.

Dr. F. J. W. ROUGHTON.—*Carbon dioxide transport in blood : recent developments* (2.45).

This paper surveys the changes in outlook which have occurred during the past three years due to—

(*a*) The isolation from red blood corpuscles of an enzyme, carbonic anhydrase, which accelerates the formation of carbon dioxide from carbonic acid, and *vice versa*.
(*b*) The evidence that some carbon dioxide may be carried in direct combination with the blood proteins, probably as protein carbamate.

Dr. THOMAS BEDFORD and Mr. A. F. DUFTON.—*Nose-opening rays* (3.15).

Leonard Hill's theory that there are ' nose-closing ' rays and ' nose-opening ' rays appeared to be of paramount importance in the study of the

physical conditions conducive to human comfort. Hill's observations are not confirmed ; in well-controlled experiments with eighty-five subjects no evidence whatever is found of ' nose-opening ' rays.

Nose-closing is found to occur not only with a dull fire but also with a bright fire. It can also be produced by heating the subject by convection (heated air) or by conduction (warm fomentation). Even the sun is a potent nose-closer.

The average person tolerates most heating effects without discomfort and without recourse to mouth-breathing ; it is only in those who are peculiarly sensitive (e.g. by reason of deflected septa) that any difficulty arises.

Monday, September 11.

DISCUSSION on *The chemical control of the circulation* (10.0) :—

Sir H. H. DALE, C.B.E., Sec.R.S.

The study of the chemical control of the circulation began with the discovery of adrenaline and of the pituitary pressor principle. The former is predominantly augmentor to vascular tone, though there is evidence that its actions include a vasodilator effect ; concerning the physiological significance of the pituitary principle little is known.

It has long been improbable that there is any organ of internal secretion which forms a hormone predominantly vasodilator in function, though depressor substances were early found in most tissues. The first of these vasodilator substances to be identified was choline. This was followed by histamine which has been shown to exert a dilator effect on the minute vessels, complicated to different extents in different species by a constrictor action on larger arterioles and venules ; this substance plays an important part in the effects of local injury to the skin. Another dilator substance, an unstable choline ester and indistinguishable from acetyl choline, is liberated as the result of stimulating various parasympathetic nerves and the arteriodilator branches of sensory fibres. Further vasodilator substances which have been discovered in recent years are the adenosine series, constituents of muscle extracts, and kallikrein, which appears to circulate in an inactive form in the blood and to be rendered active by a rise of acidity.

Evidence seems still to be lacking for the direct action of any of these vasodilator substances as a true hormone. In this respect there is a general contrast between them and the true, mainly vasoconstrictor, hormones ; this contrast, however, is by no means an absolute one, since it appears possible that adrenaline may be held in an inactive form peripherally, to be released by sympathetic nerve-impulses as a humoral transmitter of their effects.

Prof. J. H. BURN.

It has previously been shown that vasoconstrictor substances such as tyramine and ephedrine exert only a slight effect when injected into the arterial system of the body wall and limbs of cats or dogs perfused by defibrinated blood ; similarly stimulation of the sympathetic chain exerts only a slight effect. The constrictor action of tyramine, ephedrine, and of sympathetic stimulation is increased if adrenaline is continually added to the blood used for perfusion so as to maintain a uniform concentration. The addition of adrenaline has the further effect of bringing to light dilator effects following the injection of ephedrine and the stimulation of the sympathetic

chain. It is shown that the effect of a maintained concentration of adrenaline on the tyramine response is exerted *pari passu* with its effect on the histamine response, and also with a similar effect on the response to acetylcholine. The vasodilator effect of small doses of adrenaline is not seen in circumstances in which vasodilatation from sympathetic stimulation occurs. The effect of adrenaline is considered to be an effect on the vessel walls in general and not on the neighbourhood of the sympathetic terminations in the walls.

Dr. A. N. Drury.

Adenylic acid, isolated from muscle, has a depressor activity which is shared by related compounds such as adenosine, yeast adenylic acid, and yeast cytidylic acid. The last substance is of interest, as there is evidence that in muscle extracts a depressor substance is present, in addition to adenylic acid, which has very similar properties to yeast cytidylic acid. The depressor activity of adenylic acid and adenosine is lost when the amino group is split off, and this led to the idea that the effect is associated with deamination, though recent work fails to give it support. Adenylic acid has been isolated from the blood, and is considered to be the substance responsible for the 'primary toxicity' of fresh defibrinated blood. It is liberated from damaged muscle and may therefore play a part in the dilatation of vessels which accompanies injury. Moreover it produces a local dilation and leucocytosis, and may be responsible for this phenomenon of tissue damage. It is quickly inactivated by the tissues, so that it must be liberated continually if it is to produce a lasting effect.

Dr. J. H. Gaddum.

There are at least two vasodilator substances in some tissue extracts which have hitherto baffled the chemists. These have been arbitrarily called kallikrein and P-substance. They are both unstable substances with rather large molecules, and are both readily carried down from solutions by various adsorbents. Both substances produce a fall of blood pressure in animals which have received atropine, and so been rendered insensitive to choline. They are both distinguished from histamine by the facts that they are unstable in acid solutions and produce a fall of blood pressure in etherised rabbits. They are distinguished from adenosine by the fact that they are unstable in alkaline solutions.

Kallikrein has been obtained from urine and blood, but has been found to be present in a particularly high concentration in the pancreas. It is insoluble in alcohol.

P-substance is present in intestine and brain. It is distinguished from kallikrein by its distribution, and by the fact that it is soluble in absolute alcohol. There are also various pharmacological differences, but it will be difficult to obtain any certain knowledge of the general actions and significance of these substances until better methods of purification can be devised than those at present available.

Dr. W. Feldberg.

Prof. R. J. S. McDowall.

When 5 per cent. carbon dioxide is administered to a chloralised cat there may be no alteration of blood pressure, but it is not, therefore, to be

presumed that the carbon dioxide has been inactive. Such percentages of carbon dioxide have been shown by Jerusalem and Starling and others to increase the output of the heart. New experiments are described which show that the vasomotor centre has been stimulated, since there is a marked increase in the resistance of a limb perfused separately and connected to the animal only by nerves. It may therefore be concluded that, since the output of the heart is increased and the vasomotor centre stimulated without causing a rise of blood pressure, the carbon dioxide has caused a diminution of peripheral resistance. These results support the view previously put forward that the carbon dioxide of the arterial blood has in the periphery a dilator action which balances its central effect.

Prof. H. Hartridge, F.R.S. (12.25) :—

(a) *Variations in skin resistance due to electrical currents.*

Ebbecke found that the resistance of the skin to galvanic currents could be decreased either by rubbing the skin or by the continued passage of a galvanic current of such strength that whealing was ultimately produced. Lewis and Zotterman, using small electrodes, obtained a similar drop in resistance which they attributed to breaches in the horny layer, whereas Ebbecke has attributed it to stimulation of the living cells which lie deep to that layer.

I have repeated these experiments with electrodes of large area, and I find the same fall of resistance. I have noticed, however, that on cessation of the galvanic current the skin resistance rises until it reaches a value considerably greater than that to which the galvanic current had depressed it. If the explanation of Lewis and Zotterman is correct, one must conclude that the breaches in the horny layer heal again with very great rapidity.

(b) *An experiment in favour of the resonance theory of hearing.*

A brass disc, about 12 in. in diameter, is provided near its circumference with two concentric rows of slots. The inner row consists of ninety-six equidistant slots ; the outer row also consists of ninety-six slots, at equal distances except for one interval only which is half the distance of each of the others, thus introducing a change of phase (a half wave-length). When the disc is rotated by an electric motor and a stream of air is directed on to the inner row of slots, a continuous musical tone of constant pitch is produced. When the stream of air is directed on to the outer row of slots a musical tone of constant pitch is heard, but this tone is interrupted once at each revolution of the disc when the change of phase occurs. Since the interruption effect heard by the ears can be imitated by stopping up two neighbouring slots of the inner row, I conclude that this is a true interruption and not, for example, a change of pitch of the tone.

This confirms an earlier conclusion that a change in phase of a musical tone causes it to be ‘ out of step ’ with the ear resonators, so that the latter first are arrested and then recommence their vibrations.

(c) *Competitive reaction time apparatus.*

A number of neon lamps are connected so that each lamp has a separate switch. The lamps and their switches are connected in parallel between two buss bars, one of which is connected to one wire of the 200-volt D.C. main, the other buss bar being connected to the other wire of the main through a suitable resistance (usually 10,000 ohms). The current passing

through this resistance (about 10 m.a.) is sufficient to strike one neon lamp and to keep it alight, but when once this lamp has lit the resultant voltage between the buss bars is insufficient to strike any additional lamps. Consequently, when after turning on the main a neon lamp lights, it indicates that the switch connected to that lamp was the first to be closed. The apparatus can thus be used to ascertain which one of several individuals takes the least time to close his switch after a given signal which corresponds to the switching on of the main.

(d) *Advancing and retiring colours.*

'Chromatic stereoscopy' (Hartridge, *Journ. Physiol.*, lii, 222, 1918) is not limited to coloured objects, for I find that it is possible for black and white to be advancing and retiring colours when placed on backgrounds of suitable colour. Thus when they are placed on a red ground, black advances and white retires; but when they are placed on a blue ground, white advances and black retires. These relative positions may be explained as follows: A black object on a red ground is seen in the same position as a red object on a black ground would be. A white object on a red ground, however, is equivalent to a blue-green object, or a black ground plus a uniform red ground without any object on it (as may readily be seen by summing the colours). Now a blue-green object on a black ground retires relatively to a red object on a black ground and, therefore, substituting the equivalents we have just found, a white object on a red ground retires but a black object on a red ground advances. Observation shows that a white object on a blue ground advances, whereas a black object on a blue ground retires, but a white object on a blue ground may be replaced by a yellow on a black ground plus a uniform blue ground. We know, however, that a yellow object on a black ground advances, whereas a blue object on a black ground retires. Therefore we have explained the phenomenon in this case also. For grounds of intermediate colour for red and blue, namely yellow and green, the phenomenon is not so striking as it is for red or blue.

AFTERNOON.

Visit to Leicester Royal Infirmary.

Tuesday, September 12.

JOINT DISCUSSION with Sections D (Zoology, *q.v.*) and K (Botany) on *Genetics* (10.0).

SECTION J.—PSYCHOLOGY.

Thursday, September 7.

Prof. C. W. VALENTINE.—*The early development of language in the child* (10.0).

Evidence based on observations of five children from the first day to the age of 3, when all the main forms of language structure have been learned.

The essential bases of language :

(*a*) Spontaneous expressions of feeling.
(*b*) Spontaneous babblings and practice in sound making.
(*c*) Association of sounds heard with feeling, objects, or general situations.

Early effects of social influences.

Individual differences indicative of future development occur as early as 1 and 2 months. (Slower speech development of A and B as compared with Y indicated before 2 months.)

From 4 to 9 months practising of new sounds very important.

The 'understanding' of meaning of some words clearly established at 6 or 7 months.

'Understanding' and 'expression' far from identical. For expression a different word from the word heard and understood may be used for the same thing.

Prominence of feeling or conational aspect of early speech.

Importance of imitation, especially from $1\frac{1}{4}$ or $1\frac{1}{2}$ years onwards.

The generalisation of meanings; the specialisation of words.

Does the child originate words ?

Special characteristics of the period $1\frac{1}{2}$ to 2 years. Use of negative. First questions. Two- or three-word sentences.

The great discovery—'Things have names.'

From 2 to 3 years. Words indicating spatial and temporal relations. Testing by experiments the understanding of prepositions. Subordinate sentences : Why and Because. All forms of sentence structure now used.

JOINT DISCUSSION with Section I (Physiology) on *Disorientation and vertigo* (10.30).

Dr. J. T. MACCURDY.

Dependence of spatial orientation on balancing system. (Examples.) When latter disturbed, get disorientation and a secondary confusion (psychological), which produces failure to recognise objects.

Under normal circumstances balance depends on postural and righting reflexes. These are stimulated by changes in otolith organs, semicircular canals, muscle tensions, deep pressure and vision. The muscular system is the most important (Garten's experiments). It has incredibly low threshold and speed of reaction and is unconscious. There is probably awareness only for response, and for that only when exaggerated, i.e. when balance is lost ; awareness is for disequilibrium, not equilibrium. ('Falling' is a visual perception.) Disequilibrium is sensed by vision and vestibulo-proprioceptive organs.

This is illustrated in flying, which demands an acquired balancing reaction. Until this is gained visual orientation is difficult or impossible (Data). Innate balancing reactions are made to actual direction and value of *g*, but visually to aeroplane. Hence conflict and giddiness until aeroplane is treated as part of body (acquisition of manipulative control). Conflict leads to excessive proprioceptive stimuli because reaction does not abolish stimulus as in effective balancing.

This leads to nausea *via* excessive and incoordinate reflex response. Two types of sensitiveness, one to increase in value and one to change in direction of *g*. Normal response to increased *g* (alighting on ground when jumping) is tension in extensors and rigidity of abdominal walls to prevent displacement of viscera. If rapid and effective, diaphragm does not move,

and there is no consciousness of trunk muscle response. If ineffective, get diaphragmatic tug (e.g. in lift). Co-ordinate response involves accurate abdominal muscle contraction to balance g and, if this has to be maintained, a change from diaphragmatic to costal breathing. With incoordinate response diaphragm works against rigid belly wall, the abdominal contents are squeezed as in vomiting, and if this persists the whole nausea-vomiting cycle is evoked. In the other type there is a general rigidity of limbs and trunk in an exaggerated and incoordinate effort to prevent displacement of the body. This includes rigidity of abdominal muscles, and so the same result ensues.

Flight-Lt. J. A. G. Haslam.

Experiences from flying relating to the subjects of the discussion ; these will illustrate some of the points in Dr. MacCurdy's paper (*q.v.*).

Dr. T. G. Maitland.

Rectilinear movement as a cause of general vertigo—

The relation of general vertigo to special vertigo in so far as they both result from passive displacement. Among modern forms of locomotion the best example of displacement causing general vertigo is the swift vertical drop in a lift, and of that causing special vertigo the flat spin of an aeroplane.

Under which category do the movements of swings, switchbacks, of aeroplanes passing through air pockets, of boats in a rough sea, fall ? All these movements have angular direction, but the resulting vertigo is general rather than special, which implies the activity of a rectilinear factor.

What, then, is the relation of the semicircular canals to rectilinear movement ?

The reactions, both physiological and psychological, associated with general vertigo would seem to demand another receptor.

The interpretation of vertigo and its biological significance.

Sq.-Leader E. D. Dickson.

Mr. R. J. Bartlett.

Insufficiency of oxygen supply in brain owing to faulty breathing as a cause. Disequilibrium not essential. In air and water travel disequilibrium possibly a principal cause of faulty breathing. Train and motor sickness not readily so explained. Partly explained by somatic reactions to variations in speed. Complaints of vibration and noise. Noise investigation results stress psychological factors. *Some Effects of Low Frequency Vibration on Body and Mind* reported in 1930. ' Giddiness,' ' dizziness,' ' dullness,' ' sleepiness ' and ' intense cold ' induced by vibration. Accompanying pneumograph records show shallow, fluttering or panting breathing punctuated with deep gasps. The pulse also affected.

Mechanical vibration not essential. A ticking metronome induces changes in breathing of susceptible subjects. As metronome rate changes breathing changes in sympathy until it becomes impossible to change further, when there is great discomfort until subjective metronome rhythm changes to one with which breathing can harmonise. ' Torture ' due to the ' drip-drip ' of water similar. Record of a case in which the water-dripping frequency was slowing down and passed through the pulse rate.

External physical causes not essential. Purely physiological causes

sufficient. Fear, dizziness and collapse apparently due to shortage of blood in brain occasioned by digestive trouble.

Purely psychological causes effective. Fear and revival of unpleasant past experiences often reported by subjects.

Practical questions: Is a volitionally controlled breathing that will frustrate the tendency to engine control possible? Can such 'willed' breathing be transformed into a 'habit'?

Dr. R. S. Creed; Sq.-Leader G. H. Reid.

AFTERNOON.

(Section meeting in two divisions.)

Division 1.

Miss A. G. Shaw.—*Motion study applied to small assembly and machine work* (2.0).

Mr. A. Rodger.—*Why and how the vocational psychologist studies temperament* (3.30).

The term temperament may conveniently be used to cover such characteristics as are represented by the words sociability, frankness, cheerfulness, co-operativeness, neatness and cautiousness. For the purposes of the vocational psychologist most temperamental characteristics may be regarded as belonging to one of two main types; those which are displayed in an individual's attitude towards other people, and those which are displayed in his attitude towards his work. It is clear that in some occupations it is more important that a worker should possess certain of these characteristics in high degree than that he should possess either outstanding general intellectual ability or really good practical abilities. Psychologists have attempted to devise numerically-scored tests for many of them, but so far their efforts have met with scant success. The National Institute of Industrial Psychology is endeavouring to break fresh ground by adopting what may be called a 'biographical' procedure and by seeking definite assistance from the parents and teachers of those who apply to it for vocational guidance. This involves a study not only of an individual's temperamental characteristics as they are at the moment, but also of those characteristics as they have been in the past. In this way some indication of their all-important 'trend' is obtained.

Miss R. M. Goldthorpe.—*Effect of the distribution of practice periods on the learning curve in industrial operations* (4.15).

Division 2.

Dr. R. B. Cattell.—*Friends and enemies; their g, p, c, and w values* (2.0).

A previous research has shown temperament and character traits to fall into two broad patterns: the 'surgent' temperament determined by a general factor *c*, and the will-character determined by a factor *w* (Webb).

In a group of 62 students, who had been the subjects of estimates on these factors, and who had also been tested for intelligence, perseveration, and 'fluency of association,' each student was asked to name two others who were his especial friends and one other for whom he felt a particular

aversion. It was hoped that, in spite of historical accidents operating to determine many friendships and antipathies, some systematic trend, according to temperament and character similarities or differences, would be perceptible.

Indications of such relationships were found, particularly with p, c and w. (The scatter of g was so small in this examination-selected group as to make any analysis in this respect useless.) There is also an indubitable tendency for popularity (number of friends) to vary with p and w. Though the causes of these trends are obscure, confirmation and extension of these findings would make profitable discussion possible and, at the same time, throw light from a new angle on the natures of p, c and w.

Mr. F. C. Thomas.—*A simplified synthesis of the factor and noegenetic theories* (2.45).

After a brief introduction, it is assumed that the existence of general and specific cognitive factors (g and the s's) is now adequately proven. These are regarded as determining only a person's maximum performance at a given task. Factors of other kinds may, and normally do, intervene ; causing his actual performance on any given occasion to fall short of what his g–s equipment alone would lead us to expect of him. These 'quantitative determinants' of cognition fall into three classes, as follow : (1) perseveration, oscillation, constancy of cognitive output, persistence of motive and conative control of cognition—which limit achievement by affecting g ; (2) Fatigue and retentivity, which affect the s's ; (3) 'Basic constitution' (= primordial potency), or factors of age, sex, heredity, and health, which affect the other quantitative determinants. The three noegenetic processes are then regarded as being the tasks that g performs when, under the restraint of the quantitative determinants, it activates the s's.

Dr. P. E. Vernon.—*The applicability of quantitative methods to traits of temperament and personality* (3.30).

A temperamental or personality trait differs in many respects from an aptitude or ability. It cannot be defined solely in terms of objective behaviour, but is dependent upon the observation and interpretation of such behaviour by human mentalities. A man's traits are not so much his own 'properties,' as relations between him and the persons who observe him. The trait is a *name* for a very general class of behaviour, hence its content is extremely ambiguous. It is impossible to find distinct dividing lines between different traits, or to isolate any one trait as more fundamental than another.

A single test, or set of ratings, cannot give an adequate measure of a trait; instead a variety of diverse tests should be combined into a crude composite score. In personality testing, unlike aptitude testing, no objective criterion of validity is available ; but the inter-correlations within such a composite indicate its theoretical validity. Though the tetrad difference technique may be applied to these composites of personality tests, yet elaborate statistical treatment and factorial analysis are unjustifiable owing to the inherent subjectivity of the trait concept.

Mr. F. H. Gage.—*The quantitative aspect of brightness in visual sensations* (4.15).

At the meeting of the British Association last year, there was a discussion on the quantitative relation of physical stimuli and sensory events. The

following work has been performed with a view to investigating one of the simplest cases in vision, the relation between the intensity of the stimulus and the sensory brightness.

Experiments have been performed in which three white circular patches are simultaneously presented side by side on a black background. These patches differ only in respect of their brightnesses. The intensities of the two outside patches bear a known ratio to each other, while the intensity of the middle patch can be adjusted to appear equally spaced in brightness between the outer patches, that is, its brightness is neither nearer one nor the other. Using this method, it is shown that consistent observations can be obtained, and that observers substantially agree in their estimations although real differences appear between them, but that fundamental difficulties arise which prevent a scale of brightness being constructed by this method.

The experimental evidence is against the measurability of the brightness of visual sensation.

Friday, September 8.

PRESIDENTIAL ADDRESS by Prof. F. AVELING on *The status of Psychology as an empirical science* (10.0). (See p. 171.)

Dr. WILLIAM BROWN.—*The psychology of personal influence* (11.0).

The problem of personal influence arises in a challenging form in the use of methods of suggestion and hypnotism, and also in the phenomenon of so-called ' transference ' in psychoanalysis. It is important to decide, if possible, how far hypnotic effects may be explained in terms of transference, and again what are the probable bases of temperamental compatibility and incompatibility. Wider possibilities, of a spiritual and psychic nature, should not be left out of account, so far as science can deal with them.

Prof. F. A. E. CREW.—*An attempt to determine the factors operating in Professor McDougall's Lamarckian experiment* (12.0).

AFTERNOON.

(Section meeting in two divisions.)

Division 1.

Dr. R. H. THOULESS.—*Some practical consequences of phenomenal regression* (2.0).

The purchaser of a telescope for terrestrial observation wants objects to ' look big ' and not merely to make a large retinal image. Apparent size is not simply a function of retinal size. Distant large objects look larger than near small ones when their retinal sizes are equal. The extent of this effect (of *phenomenal regression*) differs in different individuals and under different conditions of perception. Monocular observation through a blackened tube is found experimentally to diminish phenomenal regression and it thus acts as a mental factor reducing the apparent magnification of a telescope. This is one reason for the greater satisfaction obtained by vision through binoculars even when these are of lower power.

Similarly a condition of lifelike representation on a screen is that the

scene represented should look large enough. The stray light in a cinematograph theatre, which gives the screen the character of a definite object at a considerable distance, favours phenomenal regression which increases apparent size. For a small screen at a short distance (such as that of a television apparatus) the best results would, on the contrary, be obtained by conditions of observation eliminating phenomenal regression as far as possible.

Ability to drive a car quickly and accurately through traffic obviously depends on ability to judge the real size of a gap at whatever distance it may be observed. Experiments have been performed in order to determine how far this ability depends on the individual's amount of the tendency to phenomenal regression (that is, on the amount of his tendency to see objects in their ' real ' sizes irrespective of their distance from him)

Dr. J. H. QUASTEL.—*Narcosis and mental function* (2.45).

The psychological effects of oxygen want (anoxæmia) resemble in many ways the reactions present in psychotic and neurotic conditions, and those found also in alcoholism and light narcosis. The study of the biochemical basis of narcosis has shown that narcotics act, apparently, by preventing the nerve cells from receiving the amount of energy necessary for their functional activity. This they do by bringing about a condition equivalent to anoxæmia, not by interfering with the amount of oxygen present, but by diminishing the ability of the cells to oxidise substances (glucose, lactic acid) which form the main fuel of the cells. Further study has shown that substances normally formed in the body and normally broken down in the liver have effects similar to narcotics, so that a disturbance of the detoxicating powers of the body might lead to conditions whose psychological reactions would resemble those found in oxygen want. The treatment of psychotic conditions by prolonged narcosis is extremely important ; it is suggested that the success of the treatment depends on the removal, during the narcotic state, of toxic metabolites (or fatigue products) in the brain. The main danger to the narcosis treatment is the disturbance in the carbohydrate metabolism in organs such as the liver whereby intense ketonuria may be established. The introduction of the glucose-insulin modification of prolonged narcosis treatment has removed this danger, so that the treatment is now comparatively safe.

Dr. C. C. HURST.—*Genetics of intellect* (3.30).

Two thousand one hundred and eighty-two parents and offspring in 406 families individually graded for general mental ability (Spearman's *g*), using scale of 11 grades (0–10) each approximately equivalent to 20 I.Q. Data include 194 modern Leicestershire families, objectively graded by author, and 212 ancient Royal Families of 11 countries in eight centuries histriometrically graded by Dr. Adams Woods. Both groups show same genetical types of families : *non-segregating* with like offspring and *segregating* with unlike offspring. Neither family environment, simple heredity nor free will can account for co-existence of these two family types exhibiting dominance and segregation. Analyses show that 98·1 per cent. of data are consistent with genetical formula of type N*n* + (A*a*B*b*C*c*D*d*E*e*) where N*n* is a major pair of genes for Normal (N) and Abnormal (*n*) Intellect and A*a*. .E*e* are minor pairs cumulatively modifying *nn* as in experimental wheats where A. .E are increasers and *a*. .*e* decreasers. Thus NN and N*n* produce normal mediocre intellect of mid-grade 5, unaffected by the modifiers, while

nn produce abnormal low and high grades 0–10, according to the modifiers present. The formula is relatively simple, involving only seven kinds of effective gametes, and is of fundamental practical importance since it predicts with considerable precision the results of any grade-matings. A scheme of family allowances based upon it would maintain minimum number of high-grade children necessary for preservation of modern civilisation.

Division 2.

Mr. R. J. Bartlett.—*The effect of so-called ' constant ' errors in sensory comparisons* (2.0).

Further work with geometric series of weighted containers. The ' constant error ' increases in amount as weight increases or decreases from a ' datum ' value. This ' datum ' not a weight or a density but a value depending on nature and size of the container. The error has sign and in adults appears to be approximately proportional to the cube of the difference between the weight lifted and the ' datum ' weight. With children the error appears to increase more rapidly.

With practice, the ' constant errors ' for a particular series decrease in amount, and possibly would eventually become zero throughout the scale. With the series used decrease is more rapid at the heavy end than at the light end, and there are indications that after the first few sittings of a subject the heavy weights are regressing towards a heavier and shifting datum, while the light ones are still referred to the original datum or to one only slightly heavier.

The common experience of subjects that discrimination is easier at the heavy than at the light end is supported by the decrease in value of the scatter error of the best equal value as the standard weight increases in value, and indicates that the true ' Weber constant ' (freed from the masking effect of the ' constant error ') slowly decreases in amount as the stimulus increases in value.

Mr. M. F. Lowe.—*Alterations in blood distribution during mental work* (2.45).

In this communication experiments with the Mosso Balance, and also with two modifications of it, are described.

Results from the simple Mosso Balance indicate that the ' head end ' of the apparatus becomes lighter during mental work, and not heavier as Mosso had stated. Further, it is shown that the conclusions of Ernst Weber in regard to the controlling influences of the position (in regard to the axis of the balance) of the abdominal organs of the subject must be revised.

In the first modification the apparatus was arranged so as to rock from side to side instead of up and down as the original Mosso Balance had done. It is shown that the approach to sleep is accompanied by a gradual depression of the left side of the balance, while mental activity is accompanied by a rise of the left side.

In the second modification the balance was constructed upon the gimbal principle so that deflections from the up-and-down Mosso motion and from the side-to-side motion could be recorded simultaneously. From these experiments it is shown that various mental states (e.g. activity, passivity, sleep) can be connected with definite combinations of balance movements.

Dr. G. Seth.—*Some clinical aspects of stuttering* (3.30).

1. The incidence of stuttering among school children. The sex-difference in the percentage of stutterers.

2. Accepted causative factors. The rôle of heredity and imitation.

3. Developmental history of the stutterer. Other neurotic manifestations. The psycho-analytic theory of the disorder.

4. The stuttering character.

(Full Section Meeting.)

Prof. E. C. Tolman.—*The learning of rats* (4.15).

Sunday, September 10.

Visit to Besford Court Mental Deficiency Institution, near Worcester.

Monday, September 11.

Joint Session with Section L (Educational Science, *q.v.*) on *The predictive value of school examinations and psychological tests* (10.0).

Afternoon.

Visit to Lowdham Grange Borstal Institution, Nottingham.

Tuesday, September 12.

Joint Discussion with Department A* (Mathematics) on *The validity and value of methods of correlation* (10.0) :—

Prof. C. Spearman, F.R.S.—*The theory of two factors.*

Foundation pillars of the theory.—Correlations between test scores ; observation of regularities ; allowances for sampling errors ; deduced constitution of scores ; other deductions.

Points on which objections have been raised.—Correspondence of theory with observation ; uniqueness of the factors ; necessary existence of the factors ; interpretation of the factors ; scientific significance of the theory.

Dr. William Brown.

As an important example of the value of methods of correlation in psychology, one may mention the employment of the tetrad-criterion ($r_{12}r_{34} - r_{13}r_{24} = 0$) to test for the presence of a central intellective factor (g). The results of an extensive research, by Dr. W. Stephenson and the present speaker, on a large and homogeneous sample of boys, using nineteen carefully selected and standardised mental tests, show a frequency-distribution of tetrad-differences in close agreement with a 'theoretical' distribution, such as may be expected from a random sample drawn from correlations actually due to one central factor, thus supporting Spearman's theory of 'g.' The form of distribution approximates closely to a Type IIa Pearson curve.

Dr. S. Dawson.

Dr. J. Wishart.—*Sampling error in the tetrad theory.*

Although much progress has been made with the establishment of the tetrad theory on a rigorous mathematical basis, the difficulties inherent in the study of the appropriate sampling errors have prevented a corresponding advance in this all-important part of the work. In deciding whether a given body of numerical data is in accordance with theory, we cannot expect the tetrads to be exactly zero, and must therefore make allowance for the random sampling error. This is usually done by forming the distribution of sample tetrads (necessarily symmetrical if each is to be counted twice, once positive and once negative), and comparing its standard deviation with an average theoretical value obtained by admittedly approximate methods. In this paper the inperfections of existing practice are noted, and some attempt is made to formulate more exactly the problems to be solved before the matter can be considered as settled. A full solution is not reached, but an extension of some earlier work of the author, in which a tetrad of product moments was used in place of that of the correlation coefficients, is suggested as a reasonable method of approach to a more exact solution. Illustrations are furnished from two series of numerical data supplied by Prof. Spearman.

Dr. S. S. Wilks.—*A criterion for testing the mutual independence of several sets of traits.*

Suppose that each of N persons has been measured on a set A of n traits, $t_1, t_2, \ldots t_n$. Furthermore, let A be subdivided into k groups $A_1, A_2, \ldots A_k$, with the i-th group A_i having n_i traits specified by $t_{a_1}, t_{a_2}, \ldots t_{a_{n_i}}$. The question with which we are concerned is the following: can this sample of Nn measurements be regarded as having come from a population in which there is no correlation between any trait of one group and any trait of another? For example, if several motor and several mental abilities are measured on a group of individuals, it might be important to ask if these two categories of abilities may be regarded as independent of each other. Again, in the problem of fitting factor patterns containing group factors to psychological data, which has been considered by T. Kelley and others, it would perhaps be useful in some cases to group the traits by *a priori* reasons and test for the significance of any dependence between the groups before attempting to find coefficients of the overlapping factors. Otherwise such coefficients may be insignificant. The same questions of independence will arise when linear transformations of the traits are considered.

If r_{pq} is the sample value of the correlation coefficient between t_p and t_q in A, D the determinant $| r_{pq} |$ of correlation coefficients in A, and D_i the determinant of correlation coefficients in A_i ($i = 1, 2 \ldots k$), then the proposed criterion for testing the significance of the mutual independence of the groups $A_1, A_2, \ldots A_k$ is $Q = D/(D_1 D_2 \ldots D_k)$. When the hypothesis is true that these measurements have been made on a group of persons which has come from a normal population in which $A_1, A_2, \ldots A_k$ are mutually independent the sampling moments are known, and in a number of cases exact expressions have been obtained for the probability integrals in terms of incomplete B-Functions. The Q criterion will be unity when, and only when, all of the r's vanish in D which do not occur in $D_1, D_2, \ldots D_k$—that is, when there is no correlation in the sample between any trait of one group and any trait of another. Q becomes zero as the hypothesis of mutual independence becomes untenable, as far as the sample

is concerned. Q may be regarded as a generalisation of $1-R^2$, where R is the multiple correlation coefficient between one variate and several others. The use of $1-R^2$ as a criterion to test the significance of the independence of one variate and a group of several others is well known. In a similar manner Q may be used to test the significance of the mutual independence of several groups of variates.

Dr. J. O. Irwin.

It is possible that coefficients of association have been used too much in psychology. They should only be used after the most careful consideration of the assumptions on which they are based, and should in any case be supplemented by statistical methods having a more direct meaning. An example of their careful use is given from some of the work done for the Industrial Health Research Board on "Tests for Accident Proneness," by Messrs. Farmer, Chambers and Kirk.

Prof. H. T. H. Piaggio.

How far is g determinate? Analysis of tests by Murdoch, Brown, and Stephenson. No appreciable increase in determinateness possible by further increase in the number of tests. New tests with greater g-saturation needed.

Afternoon.

(Section meeting in two divisions.)

Division 1.

Prof. C. Spearman, F.R.S.—*The international plan for determining an individual's unitary traits* (2.0).

Unprogressiveness of psychology; revolution and evolution.

Scheme to determine unitary traits; Thorndike's plan; formation of committee; extension of plan.

International aid up to the present; fundamental objections; constructive suggestions.

Experimental investigations already in progress: London; New York; Nashville; Washington; Chicago.

Mathematical advances made in theory of factorisation.

Collaboration for the future: criticism; corroboration; supplementation; interpretation; special controversies; final general conference.

Dr. G. G. N. Wright.—*Personal relations and the small group* (2.45).

Two minds come into relation with one another when each seeks expression in a frame of external circumstances of which the other is a part. A sociological view of such an event must apprehend the points of view of both persons as equally parts of one sociological situation which comprehends the relevant mental states and behaviour of both. When these are in *concord*, and a common programme of activity follows, the dispositions in both minds which determine it may be regarded as constituting a single functional system or *common mental frame*. The general lines of the more primitive common mental frames are innately determined; but (*a*) they undergo modifications specific to particular personal relations, and (*b*) *co-operative relations* may rest upon common mental frames which have little or no innate basis but arise out of: (i) similar responses to a common situation; (ii) complementary responses to a common situation; (iii) the

pursuit of a common end; (iv) the pursuit of interdependent ends. The structure of human relations is further complicated by (α) the development of *regulative mental structures*, (β) volitional processes and *other-consciousness*.

The structure of all groups small enough to be accessible for this kind of study may be described in similar terms.

Miss M. D. Vernon.—*Binocular vision of flickering fields* (3.30).

Differing fields illuminated by steady or flickering lights were presented separately to the two eyes. The critical frequency of flicker was higher when both fields were flickering than when one field flickered and the other was dark, showing that a binocular summation of brightness occurred. If one field was illuminated by flickering light, and the other by a steady light of equal or less brightness, no increase of critical frequency occurred, showing that there was no binocular summation of brightness. If the steady light was much brighter than the flickering light, the flickering frequency was slightly decreased.

If figures of differing complexity were introduced into the steadily illuminated field, or into both fields simultaneously, there was in general a decrease in the flickering frequency. This seems to show that the critical frequency of flicker is a function of the nature of the fields, as well as of their brightness, and that perceptual factors are of importance in determining the critical frequency.

Division 2.

Mr. N. M. Balchin.—*A psychological approach to market research* (2.0).

It is a mistake to think of market research as a new development. There has always been market research of a crude, unconscious type. Recent workers have sought to make market research an exact, numerical science, in which the consumer is wrongly considered as a mechanical and invariable unit.

True market research is not, and cannot be, a mathematical science. The collection, classification and numerical analysis of data are necessary preliminaries, but the essence of market research lies in the interpretation of this data, not in terms of numerically expressed fact, but in terms of psychological tendency.

The examination of the present state of a market is the beginning of market research, but its end, if it is to have a constructive value, is less concerned with *what* people do than with *why* they do it, and less concerned with what *is* than with what *will be* in certain changed circumstances.

If market research is to continue and develop, it must provide constructive suggestions rather than statistical information. To that end it must study the psychology of the customer and his probable reaction to change rather than his conditioned responses to present circumstances.

Market research must be a market barometer, *not* a market thermometer.

Mrs. W. Raphael.—*A comparison of the psychological effects of employment by the Civil Service, by large companies, and by 'family' firms* (2.45).

There is a tendency for the goodwill of the worker towards the concern in which he is employed to vary inversely with the size of the concern. An attempt is made to study the causes of this tendency, such as the increased subdivision of labour in large concerns, the loss of direct contact

with the management, the reduction in opportunities for promotion and the increase of interdepartmental jealousies.

The attitude of the lower grade civil servant towards his work is very unlike that of the average employee of a business house. This may be partly due to different methods of recruitment, but is largely the effect of certainty of employment, regularity of promotion and the traditions of the service.

The modern trend is towards larger groupings of employees, both in state and in commercial undertakings. Suggestions are made for minimising the resulting bad effects for the worker.

Mrs. N. M. Barnes.—*The function of the psychologist in the administrative scheme* (3.30).

The psychologist should be a recognised factor in the scheme of every local authority. His functions will be both practical and advisory. He should keep in touch with the problems of the normal school, and be prepared to give advice in those matters where his scientific training is likely to be of special value.

It will also be his function to deal with variations from the normal, and to examine and advise the cases of special difficulty of learning or behaviour. He should be able to draft children to some school in the area where such cases can be dealt with. He would act in an advisory capacity to such a school and keep in touch with the children's progress.

He should devise means for keeping in touch with the problems of parents and teachers, of keeping them informed of such discoveries in psychology as are of special importance to educators, since the success of his work is dependent on the degree of intelligent co-operation he can count upon.

SECTION K.—BOTANY.

Thursday, September 7.

Prof. A. C. Seward, F.R.S.—*The past and present floras of the Kerguelen Archipelago* (10.0).

The occurrence of the fossil coniferous wood in beds believed to be Tertiary in Kerguelen Land has long been known. A few years ago Dr. de la Rüe collected several specimens of impressions, the best of which are foliage shoots and cone scales of *Araucaria* ; he found also fragments of ferns and imperfectly preserved leaves of Angiosperms and other plants. A general account of the geological and physical features of the Archipelago is given, and the main features and geographical relationships of the present flora are discussed.

A brief description is given of the fossil plants, the age of which is believed to be Tertiary. Special attention is paid to the geographical range of present and past representatives of the genus *Araucaria*. The main purpose of the paper is to draw attention to phytogeographical and palæogeographical problems raised by the recent discovery, particularly to the difficulty of finding satisfactory solutions without assuming the movement of land masses.

Dr. H. Hamshaw Thomas.—*The nature and origin of the Stigma* (10.45).

The conventional view of the carpel is a purely subjective concept. An objective treatment of carpel morphology at once demands a provisional solution to the question of the origin of the stigma. The suggestion that the evolution of the stigma preceded the inrolling of the carpellary leaf involves physiological improbability. In seeking a new explanation we need to know more of the structure of the stigma, and of the cells or tissues which conduct the pollen tubes to the micropyles. The existing information furnished by Capus, Guéguen, Juel, and others has been almost entirely ignored by English and German morphologists. 'The stigma is only the upper termination of the " conducting tissue " of the style' (Capus). This tissue usually extends downwards as a definite band or bands on the ovary wall to the vicinity of the ovules; it appears to originate from papillate cells with specialised contents, but becomes much modified in certain families (e.g. Compositæ), especially in the style. In many cases the conducting tissue extends to the bottom of the gynæcium before entering the ovary, and it seems only possible to explain this on the assumption that the conducting tissue (and therefore the stigma) originated at the base of the ovary and later extended upwards. The structure and development of the carpel and stigma in *Alchemilla*, *Rhodotypus*, and other members of the Rosaceæ supports this idea.

On this assumption a picture of the evolution of the stigma and carpel can be drawn which is possible from both the morphological and physiological standpoints, the carpel wall representing two fused pteridospermous cupules. This view provides an explanation of what we know about the early stages of carpel development, of the vascular system of the carpel and of the anatropous ovule. We now know of fossil plants which exemplify most of the earlier stages in the supposed sequence of events.

The angiospermous flower is not homologous with a vegetative bud, and it is quite possible that the Rosaceæ may be one of the more primitive families now living.

Joint Discussion with Section A (Mathematical and Physical Sciences, *q.v.*) on *The X-ray analysis of fibres* (11.0).

Alternative programme for Members not attending the above discussion :—

Prof. H. S. Holden.—*On a new pteridosperm stem from Shore* (11.5).

The specimen described is a stem which has a markedly stellate outline in transverse section. There is a small homogeneous pith surrounded by primary xylem with mesarch protoxylem. The leaf-trace is mesarch and undivided. In common with the group of species described by Kubart, this stem forms a link between *Lyginopteris* and *Heterangium*.

Prof. J. Doyle.—*The nature of heterospory* (11.20).

Dr. T. M. Harris.—*On the reproductive organs of some early Bennettitales* (11.40).

Prof. R. A. Fisher, F.R.S.—*The genetical system responsible for ever-sporting stocks* (12.10).

An outline of Winge's theory of doubleness in stocks, and of its implications, is given.

A simple method of diagrammatic representation, applied to Miss Saunder's data of 1911, shows both that the observed excess of doubles is due solely

to their greater viability, and that one family there reported was exceptional in giving one-quarter doubles, as should the progeny of a plant freed from the pollen lethal.

The close linkage between the pollen lethal and the factor for doubleness is due to selection acting automatically in the propagation of the ever-sporting lines, which has thus built up the ever-sporting character.

Afternoon.

Prof. N. G. Ball.—*The effect of nocturnal illumination on the subsequent opening of flower buds* (2.0).

The flowers of certain plants, *Turnera ulmifolia* var. *elegans*, *Asystasia gangetica*, *Ipomœa* spp. and others, which normally open in the morning, are markedly affected when the buds are subjected to light during the previous night. In buds which have been treated in this way, the petals, although they become elongated, may fail to diverge, and short-lived flowers may become withered while they are still in the closed condition. A somewhat similar result is obtained when the buds are illuminated two nights before they are due to open, even if this is followed by normal conditions during the second night.

In most species where this effect of light has been observed, the failure of the flower to open is correlated with a partial inhibition of the normal hydrolysis of starch in the petals. This inhibition is associated with a decrease in the diastatic activity of the cell-sap.

In the case of flowers which react in this way, a comparatively weak illumination during the night is sufficient to prevent the buds from opening. When a screen which only transmits the red rays is placed between the light and the plant, the result is the same as it is with white light, but the infra-red rays alone do not have this effect. On the other hand, when buds are exposed during the night to the blue and violet rays only, even when the intensity of the light is considerably increased, they behave in a similar manner to those which have been kept in the dark and open normally.

Dr. B. T. Cromwell.—*Berberine in the metabolism of Berberis Darwinii* (2.30).

Experimental evidence leads to the deduction that the alkaloid berberine is a waste product of metabolism, and that it is produced in largest amounts when conditions favourable for protein breakdown are realised. Accumulation of the alkaloid in the root and stem bark takes place from year to year. Application of inorganic nitrogenous salts alone does not lead to increased alkaloid production, but if, in addition, glucose is supplied, or organic nitrogenous compounds, such as asparagine, are applied alone, rise in berberine content is observed. Light is an important factor in the synthesis, and all tissues growing in absence of light show high values. In shoots which have been grown for alternate periods in darkness and in light, only those regions which have made growth in absence of light exhibit high percentages of alkaloid. Withdrawal of essential elements leads to variations in yield. Under conditions of nitrogen starvation, alkaloid still accumulates: therefore it does not play the part of a nitrogenous reserve. Deprivation of calcium does not check berberine production, but withdrawal of potassium appears to inhibit synthesis. It is suggested that the alkaloid is synthesised from carbohydrate and protein residues.

Excursion to Charnwood Forest.

Friday, September 8.

Miss L. I. Scott and Prof. J. H. Priestley.—*On the Monocotyledon shoot from the standpoint of development* (10.0).

Miss M. T. Martin.—*The structural and other differences between Suæda maritima and S. fruticosa* (10.40).

Suæda maritima and *S. fruticosa* are both maritime plants found on the coasts of Britain; the former is a small herbaceous annual inhabiting the lower levels of salt marshes, and the latter is a shrubby perennial found characteristically on maritime shingle banks. The present investigation includes a morphological and anatomical study of the two species, together with an attempt to correlate their outstanding features with some of the environmental factors involved.

In the first part of the paper a brief account is given of the two species; their habit, distribution, and the chief features of their habitats. This is followed by a brief summary of their anatomical characters, selection being made of any features of special interest, and particularly of the main points of difference between the two. Finally, an attempt is made to correlate these results with the environmental conditions, and to point out any bearing which they may have upon the general problems of halophytic vegetation.

Miss M. M. Chattaway.—*The development of the rays of the Sterculiaceæ* (11.20).

The development of the rays in the wood of the Sterculiaceæ has been studied by means of serial tangential sections. New rays originate either by subdivision of a fusiform initial or by the splitting up of a large ray; the latter process appears to be closely related to a low surface-volume ratio in the larger rays, and is achieved by the reversion of ray initials to the fusiform condition, and not by the intrusion of adjacent initials.

The number of initials in the rays is increased either by the swelling and division of existing ray initials, or by the addition of fusiform initials which are converted into ray initials, this latter method giving rise to sheath cells (*hullzellen*), which are characteristic of the Sterculiaceæ.

In what appear to be the more advanced woods of this family the size of the rays is strictly limited, and fusiform initials are only converted to ray initials for the formation of new rays. These small rays are often very numerous, their surface-volume ratio remains high, and the reversion to fusiform initials and splitting of the rays does not occur.

Prof. F. E. Lloyd.—*Is Roridula to be regarded as carnivorous?* (11.50).

The two species of *Roridula* (*R. gorgonias* and *R. dentata*) are conceded to be carnivorous. This concession appears to be based on their taxonomic position as Droseraceæ and on their possession of glands which simulate those of *Drosera* in form. Fenner (*Flora*, 1904) showed, however, that their histological structure is different. As he worked on herbarium material, he naturally overlooked an important fact—namely, that the abundant secretion, which does indeed trap insects, is not water-soluble, but is rather a resin or an admixture of resins. It is soluble in ether, acetone, etc., and is acted upon by alkali and acid, being changed into a brittle, frothy substance. There are no glands which secrete a water-soluble mucilage, nor any glands which might be regarded as digestive, comparable to those of *Drosera*.

The gland in its simplest expression—i.e. a small one—consists of four

longitudinal series of epidermal cells with a thick cuticle. In a large gland the number of longitudinal series of cells is multiplied and the interior is now occupied by a parenchyma. Thus far, Fenner is correct. There are, however, no pores or fissures in the cuticle, the sole opening being apical and schizogenous (Lloyd, *Trans. R.S.C.*, 1933). Leading to this opening there are intercellular canals, one between each two longitudinal series of epidermal cells and bulbous towards its proximal end. These are filled with the resinous secretion, which escapes only through the apical opening. The findings indicate a negative answer to the question proposed.

Dr. E. N. MILES THOMAS.—*Recent work on the significance of seedling anatomy* (12.0).

AFTERNOON.

Prof. Dame HELEN GWYNNE-VAUGHAN, G.B.E., and Mrs. H. S. WILLIAMSON.—*The development of Ascophanus aurora* (Crouan) Boud. (2.0).

Ascophanus Aurora (Crouan) Boud. is a minute, coprophilous fungus; it is monœcious and homothallic. The antheridium is globular, borne at the end of a stalk. The oogonium is ovoid, somewhat twisted, with a multicellular trichogyne. The sexual nuclei fuse in the oogonium and a few relatively large ascogenous hyphæ grow out, in which the nuclei lie in single file. After simultaneous division of the nuclei in the ascogenous hyphæ, walls are formed across the spindles, so that the hypha is divided into a terminal uninucleate cell, a basal uninucleate cell, and an intervening series of binucleate cells. Asci are formed in the usual way, and three successive divisions give rise to the nuclei of the ascospores.

Miss M. NOBLE.—*The life-history and morphology of Typhula trifolii* Rostrup (2.30).[1]

The life-history and morphology of *Typhula trifolii* has been investigated. Sclerotia are formed in multispore cultures, and these germinate freely and produce the hymenophores ; the latter are also produced directly from the mycelium.

The fungus is probably heterothallic ; clamp connections are present in multispore cultures but are not found in the monospore cultures, and these latter do not produce typical sclerotia or hymenophores.

The parasitism of *T. trifolii* is being investigated. The distinctions between *T. trifolii*, *T. betæ* and *T. variabilis* are not well defined.

Dr. B. BARNES.—*British aquatic fungi* (3.0).

The lower Phycomycetes have been little studied in Britain, but many species have been described in Europe and in North America. Recently, several interesting forms have been found in this country. They have been obtained from masses of moribund algæ, from twigs, and from other vegetable debris taken from reasonably clean ponds and ditches. Such substrata, when placed in small quantities in one to two litres of cool, clean tap water, will sometimes develop crops of Phycomycetes in a week or so. Sterilisation of the water is not necessary unless it is desired to show that a given fungus occurs in a given body of water. The fungi found include species of *Monoblepharis*, *Gonapodya*, *Rhipidium*, *Sapromyces*, *Pythiomorpha*

[1] In the absence of Miss Noble owing to an accident, the communication was read by Dr. A. H. Campbell.

and *Pythiogeton* ; it is probable that further search will add *Allomyces* and *Araiospora* to the British flora.

The peculiar Hyphomycete, *Tetracladium Marchalianum*, sometimes occurs among dying algæ.

Other interesting Phycomycetes, in particular *Thraustotheca clavata* and *Geolegnia inflata*, have been obtained from the soil of a garden in South London. These fungi, with species of *Pythium*, and numerous forms not yet identified, developed on boiled cress seeds placed in a shallow layer of water and soil and subsequently transferred to clean water.

All these forms deserve further study, as they are of great interest morphologically, and of importance taxonomically.

Saturday, September 9.

Excursion to the Peak District.

Sunday, September 10.

Excursion through Rutland (*via* Oakham), Stamford, etc.

Monday, September 11.

Presidential Address by Prof. F. E. Lloyd on *The types of entrance mechanisms of the traps of Utricularia (including Polypompholyx)* (10.0). (See p. 183.)

Prof. J. McLean Thompson.—*On the acarpous nature of certain forms of inferior ovary* (11.30).

Within recent years the author has been privileged to examine a wide range of Scitaminean plants, and in particular to examine the development and morphology of their inflorescences.

He has been compelled to the conclusions that many forms of cymose inflorescence in the affinity have arisen by reduction of branched cone-bearing strobili, with flowers arranged in spiral order, and that sub-floral branching is not involved. The final stages in reduction of the intermediate cymes are simple spikes.

The flowers themselves are considered to have been crateriform, with vegetative organs displayed in spiral succession on the outer surface of the crater and with microsporangiophores on and towards the rim. There were neither carpels nor styles, but the crater was occupied by megasporangiophores produced in spiral manner. The latter are the modern ovules. The crater is considered to have been reduced and its margin to have been curtailed, so that upper microsporangiophores came to lie on the inner rim. Here they were sterilised to styles, and their subjacent areas of support within the crater became the modern placentæ. The acarpous view of the ovary is supported by evidence of progressive contribution of the andrœcium to the style without involving the organisation of the ovary.

Mr. F. F. Hyde.—*Notes on the floral morphology of the Campanuloideæ* (12.15).

The structure of the flower in a number of genera is described with special reference to the vascular anatomy. The bearing of the investigation on

such problems as those of the syngonous condition (epigyny) and the nature of the gynæcial members is indicated. Reference is made to the floral development of some of the species. The paper constitutes a preliminary account of an investigation of the floral structure throughout the Campanulaceæ.

AFTERNOON.

Exposition of exhibits in the laboratories of the Department of Biology, University College, Leicester (2.15).

Tuesday, September 12.

JOINT DISCUSSION with Sections D (Zoology, *q.v.*) and I (Physiology) on *Genetics* (10.0).

Alternative programme for Members not attending the Genetics Discussion :—

Prof. F. A. F. C. WENT.—*Recent progress in the study of growth-substance (Auxin) in plants* (10.0).

Although growth substances in plants (auxins) have been studied elsewhere, the present paper is limited to an account of the work done in the Botanical Laboratory at Utrecht. As far as the influence of auxin on the cell wall is concerned, Heyn is continuing the studies he began at Paris and Leeds (i.e. X-ray investigations of cell walls), which led him to distinguish between plastic and elastic extension. The first of these is due to the action of growth substance and is irreversible. The elastic extension can be explained by a relaxation of the outer layers of the cell wall, due to the influence of strain. By studying the load extension relationship of the wall he was able to provide an explanation of differences of *elastic* extensibility, which occur as a result of changes of the rate of elongation.

A study of phototropism with seedlings of *Raphanus* and *Lepidium* made by Van Overbeek has given results by which a synthesis of the theories of Blaauw and F. W. Went could be obtained. Here the auxin is produced in the cotyledons under the influence of light, and it flows towards the base in a longitudinal direction so long as the seedlings are kept in the dark or are equally illuminated on all sides. If, however, unilateral illumination is used, the flow of auxin is diverted laterally, so that the shaded side gets more growth substance than the other one and consequently grows faster. A curvature therefore results.

On the other hand, light has a very distinct retarding influence on the growth of these seedlings. It may be proved that this—which is obviously the light-growth reaction of Blaauw—is due to a diminished sensibility of the cells to growth substance. The same quantity of auxin with the same cell gives a greater elongation in the dark than in the light ; whether this is a direct action of radiation on the cell walls or not has yet to be seen. Lateral illumination thus has two different effects on the seedlings of *Raphanus sativus*—(1) it diverts the growth substance to the shaded side, in consequence of which this side will grow faster ; (2) it diminishes the reaction of the illuminated cells to growth substance, in consequence of which the illuminated side will show a lesser reaction. Both effects are additive, and the result will be a positive phototropic curvature, the amount of which could be calculated by Van Overbeek. A somewhat similar

explanation, though not going so far, has been put forward by Du Buy for the phototropic curvature of oat seedlings.

Dijkman, studying the geotropic curvature of seedlings of *Lupinus*, has shown that here also the explanation of Dolk holds good. When these seedlings are placed in a horizontal position the distribution of the auxin is altered, the lower half getting more than the upper one ; consequently it must grow faster, and a negative geotropic curvature results. The amount of the curvature may be calculated from the distribution of the growth substance.

Bottelier has made a study of protoplasmic streaming in the coleoptile of *Avena*. The influence of temperature is small in young plants, but in older ones he obtained a ratio for the velocity of streaming at 16·5° C. to that at 24° C. of 10 to 21·3, which is almost identical with the ratio found by Van der Wey for the velocity of the transport of auxin. Light, especially of short wave-length, has a very pronounced influence on the velocity of protoplasmic streaming ; it is very remarkable that this influence is almost the same as in the light-growth reaction according to the data obtained by Van Dillewijn several years ago.

The amount of protoplasmic streaming was not always the same, but it became evident that it changed with the sensitivity of oat seedlings to the growth substance. This amount is small when the sensitivity is low, and greater with a higher sensitivity.

An investigation into the factors which influence this sensitivity in a room kept at constant temperature and constant humidity is in progress under the auspices of Kögl, and is being carried out by Haagen Smit and J. J. Went. There is sometimes a certain periodicity in this sensitivity, so that at a certain time of the day it is high, at another time low. They could get rid of this periodicity by the use of metal boxes in the constant temperature room. Whilst it was not necessary to make use of leaden boxes, they had to be made of a good conductor of electricity. Hence it was clear that cosmic rays had no direct influence on the phenomenon, but possibly the electrical conductivity of the air played some part in it. The investigators could alter the sensitivity of the seedlings by passing a feeble electric current through them. When the tip is negative with respect to the base the sensitivity is lowered ; in the opposite case it can be carried up to an amount never yet found under natural conditions. The currents necessary for obtaining the same deviations of the sensitivity as under natural conditions were of the order of 10^{-8} ampere. Oat seedlings are remarkably good objects for such experiments, since the effect can be quantitatively measured in them much better than in other cases.

Miss E. N. Sparshott.—*Tuberisation, with special reference to the development of Testudinaria elephantipes* (10.40).

The adult tuber of *Testudinaria elephantipes* is semi-globular with a flattened base from which roots arise centrifugally. Except at the apex the surface is covered with cork, thin over the base, but thick and deeply fissured elsewhere, owing to internal growth. Each season one or more new climbing vegetative shoots develop in the axil of one of the scale leaves surrounding the apex of the tuber.

The embryo shows no tuberisation. The plumule remains very short and bears one relatively large leaf. Assimilates accumulate in the hypocotyl, which rapidly undergoes tuberisation. Early thickening results from division and hypertrophy of existing cells. Tuberisation is continued by secondary growth mainly from a pericyclic ' growth zone,' but also from

successive phellogens. The ' growth zone ' resembles an inverted cup with a hole in the bottom—i.e. beneath the apex of the tuber. Apex and base are further developed from the surrounding meristem and respectively produce a sympodium with reduced internodes and fibrous roots.

Adventitious buds may develop when a fissure penetrates beneath the ' growth zone ' and causes its cells to collapse in that area. The conditions thus brought about are comparable with those obtaining at the tuber apex.

Miss L. M. Wicks.—*The significance of the inverted bundle system* (11.20).

In Amaryllidaceous leaves the development and course of the vascular system was studied, especially in concentric leaves on account of the presence of two systems of vascular bundles : (i) a system of large normally orientated bundles ; (ii) an adaxial system of small inverted bundles. Throughout the leaf-limb the two systems are connected by transverse commissures. In the leaf-base the relationship of the inverted bundle system to the normally orientated one and to the stem system varies, and the following three types were found :

(1) *The Ianthe type.*—Certain normally orientated bundles in the bifacial leaf-base curve round and enter the concentric leaf-limb as inverted bundles.

(2) *The Agave type.*—The inverted bundles are formed by special branches given off from the normally orientated bundles in the leaf-base.

(3) *The Narcissus type.*—The most marked variation occurs in *Narcissus*, where the inverted bundles pass down from the leaf-limb into the upper part of the leaf-base, where they end abruptly in groups of small tracheids.

According to the Phyllode theory the concentric monocotyledonous leaves are morphologically petioles, the inverted bundles resulting from the flattening of a petiole with a circle of vascular bundles as seen in transverse section. It is difficult to see how such variations as shown in the three types here enumerated can be made to fit in with the phyllode theory.

The inverted bundles can be considered as secondary structures developed during the evolution of the primitive monocotyledonous leaf, possibly to increase the amount of vascular tissue in order to supply the increased amount of assimilating tissue of the concentric leaf.

Prof. G. Senn.—*The influence of light on the permeability of the plant cell* (12.0).

Afternoon.

Business Meeting of the Section (2.0).

Discussion on *The teaching of botany in courses of biology* (3.30).

Prof. J. R. Matthews.—Semi-popular lecture—*The British flora and some of its problems* (5.0).

Wednesday, September 13.

Visit to demonstration by the Timber Fireproofing Co., Ltd., Market Bosworth (10.0).

DEPARTMENT OF FORESTRY (K*).

Thursday, September 7.

CHAIRMAN'S ADDRESS by Major the Hon. RICHARD COKE on *A system of forestry for the British Isles* (10.0).

(1) The need for a system which is in accordance with nature's methods and which, besides aiming at the production of timber of the utmost commercial value that is possible under the local conditions, has due regard for sporting amenities.

(2) Reasons for and against planting large blocks of one species only.

(3) Reasons for and against uneven-aged mixed woods known as '*Jardinage*' in France.

(4) The prevalent neglect of encouraging natural regeneration in the British Isles, and the economic importance thereof.

Lt.-Col. E. PRATT, M.C.—*Factors affecting the propagation and rate of growth of Salix cœrulea* (11.0).

At its meeting last year, this section of the Association discussed the systemity and origin of the cricket-bat willow, and Dr. Burtt Davy expressed the view, which was undisputed, that the Essex or Chelmer Valley strain was, whatever its origin, the most reliable one for growers to plant.

Having decided on the correct strain, we need to consider the factors which produce the growth of the large rings of white wood needed to make the popular light cricket bat.

Salix cœrulea is a tree naturally producing a red timber. The cricket-bat manufacturer aims at a bat weighing a little over two pounds, and the best way to obtain this is from trees which have made such a rapid growth, that seven to eight years' thickness of white sap wood is obtainable. This can only be done by considering every factor which tends to produce rapid growth, and by utilising the timber before that growth has been checked.

The factors to be considered are, the wood of the original cutting and its development into a strong pollard, the cultivation of the shoots of that pollard to produce the quickest and straightest growth, the question whether the set should be put in the nursery to grow a root before planting out, the best conditions as to site and propinquity to other trees, the manuring, pruning, and after-care of the growing tree, precautions against disease, and, finally, the decision as to the best age at which to sell and the best method of marketing.

Mr. WM. DALLIMORE.—*Trees and the countryside* (12.0).

The important part played by trees in the landscape effect of the countryside is emphasised, with special reference to park, field and hedgerow trees, as apart from those grown in woods and forests. Some of the forces operating against the maintenance of such trees are discussed, and suggestions made for the better selection of trees for planting in small shelter woods, and spinneys, and in hedgerows on large estates and farms, with a view to maintaining the amenities of the countryside and bringing profit to the owners. Reference is also made to the need for better cultural care in the management of park and hedgerow trees. Attention is directed to the danger to healthy trees by allowing dead, dying and otherwise worn-out

trees, that have no definite historic value, to stand in fields, woods and parks, and a plea is made for their removal and for planting young trees to take their places.

AFTERNOON.

Excursion to Nanpanton, Loughborough *via* Thurcaston, Woodhouse, visiting Olverscroft Priory and Bradgate Park (by permission of Alan Moss, Esq.).

Friday, September 8.

Mr. H. MUNDT.—*Good forest and thinnings* (10.0).

Foresters utilise results from the past, live by the present, and work for the future. Aims and means ought to be discussed, understood, explained by measurement, graphs and valuations, suitable for international intercourse. Forests characterise a country and react strongly upon the life of men. A complex of ' stands ' and ' cultures ' do not suffice ; *a forest* is required : natural, vigorous, with big trees and great values, in constant activity everywhere, beautiful and still rooted in sound economy.

Thinnings every two to five years can transform the forest astonishingly and augment both revenue and capital-value considerably. Where 10 to 15 per cent. of the volume each two to five years is a reasonable revenue, three times as much every six to fifteen years will be destructive. By constantly assisting the best and biggest trees, we can improve the assimilation system, the forest climate, self-sowing, the form of young plants and the flora and fauna. Moderate volumes of great value and big increment can be furthered and the periods of fallow, so ruinous for forestry-economy, avoided.

Wonderful progress is obtained by new species of trees and better race, but above all it is good forestry to make the most of what already exists and carefully keep up that continuity which belongs to nature.

Mr. JAMES MACDONALD.—*Some effects of thinnings in coniferous plantations* (11.0).

Mr. A. P. LONG.—*The utilisation of thinnings* (12.0).

AFTERNOON.

Visit to the timber yards of Messrs. W. Gimson & Sons.

Saturday, September 9.

Excursion to Boughton Estate near Kettering (by permission of the Duke of Buccleuch).

Sunday, September 10.

Excursion to Belvoir (by permission of the Duke of Rutland).

Monday, September 11.

The Hon. NIGEL A. ORDE-POWLETT.—*Forestry and sport* (11.15).

Debt of forestry to sport in the past. Large areas planted for covert that would otherwise have remained derelict. Original natural woods

maintained through early and middle ages solely for sporting purposes. On majority of estates before the war little planting but for sport. Debt of sport to forestry, very little owing to general absence of organised forestry. Introduction of new species cuts both ways. Present-day position. Universal interest both in sport and forestry. Financial importance of both subjects. Vital necessity of friendly relationship. Pessimism no excuse for inaction. Points of contact. Very large areas of woodland are of no value for sporting. Ground game should not come under sporting. Pheasant and grouse shooting the only types of sport affected by forestry. Very few grouse moors should be afforested from the financial or silvicultural point of view. Pheasant shooting inevitably very closely bound up with forestry. Requirements of pheasant pr serves. Coverts, nesting ground, flushing points. Effects on these of systematic forest management. Importance of size and distribution of woodland area upon the sporting. Treatment of (*a*) large blocks, (*b*) scattered woodlands. Formation of flushing points for permanent covert.

Dr. M. C. Rayner.—*An account of recent experimental work on Mycorrhiza in relation to forestry.*

Experimental evidence is offered that there exists a direct causal relation between presence of mycorrhiza (where there is evidence of normal functioning) and satisfactory growth in seedlings of several species of Pine.

On soils where formation of mycorrhiza by young trees is inhibited or markedly delayed, it can be expedited by inoculation of seed plots, previous to sowing, with small quantities of humus known to contain active mycorrhizas of the host tree.

It is not believed, however, that this treatment alone will remove the trouble permanently on certain soils, since the development and functioning of healthy mycorrhiza is conditioned by the physiological state of both roots and mycelium. This in turn is bound up with environmental soil factors, and it may be expected therefore that experimental modification of such factors will be reflected in the condition of the root system, both in regard to the amount and kind of mycorrhiza formed.

Following the adoption of a working hypothesis that the correct environment is bound up with certain humus constituents of the soil, the results of experiments involving the application of special organic composts are described and illustrated by means of lantern slides.

Tuesday, September 12.

Mr. J. A. B. Macdonald.—*Preliminary results from peat planting experiments at the Lon Mor Experimental Station* (10.0).

This area of poor Scirpus peat moorland was selected in 1925. The exposure is full and the underlying rock an acid gneiss.

Before draining the dominant *Scirpus* was accompanied by much *Erica tetralix*. In addition to *Sphagnum* species *Rhacomitrum* was frequent. The lichen *Cladina* and the liverwort *Pleurozia* also occurred.

Previous investigations had shown notched planting to be radically unsuited for this type of ground.

To permit plant roots to ramify without delay the system of planting, later to be known as the ‘ shallow-turf ’ method, was devised.

From an early date it was intended to investigate mechanical means of draining and turf provision in order to reduce otherwise prohibitive costs.

Amongst projects tackled experimentally were the following :

(1) Method of inserting plants into a shallow turf and comparison of single shallow turf-method with other systems of turf planting.
(2) Manuring and top dressing, chiefly with phosphates ; inoculating with active peat.
(3) Effects of shelter.
(4) Effects of preparation in advance and of turf decomposition ; season of cutting peat.
(5) Use of peat from different depths.
(6) Intensity of drainage.
(7) Age and type of plants.
(8) Trials of different species and races.

Several of the experiments embraced costing trials.

Experimental lay-out of various kinds has been used.

Preliminary results show amongst other things :

(*a*) The successful start made by surface planted trees.
(*b*) Beneficial effects from phosphatic manuring.
(*c*) Preparation in advance is, apparently, unnecessary.
(*d*) Shelter is of secondary importance.
(*e*) Surprisingly good growth of various exotic conifers compared with species previously considered more hopeful.

While results obtained are only of a preliminary nature everything points to the urgent need for—

(1) Cheap draining and turfing by mechanical means.
(2) Cheap supply of suitable phosphatic manure.

Mr. W. A. Robertson.—*Public opinion in the Empire upon forestry* (11.0).

Forestry is an unpopular subject or, at best, of indifferent interest to the public in the Empire and in the English-speaking part of the world. Why is it so ?

In the Dominions and probably most of England, forestry stands for plantation work and little or nothing else, and plantation is associated mostly with conifers, and exotic conifers at that. Apart from this, forests are only associated with collections of decaying veteran trees esteemed for picturesque or sentimental reasons.

The reliance on imported supplies of timber is of very old standing, while home woodlands are associated with sport only. Does this account for public indifference to forestry ?

To get forestry properly appreciated in England and the Dominions ought not the supporters of forestry to try to give emphasis to the position of forests as part of the general land economy of the country and demonstrate the continuity of forests : the employment they give, the tending, protection and management that they require ; and get away from the idea that forestry means the planting of an area and its neglect until the owner wants some cash ? Some suggestions as to how this may be tried for, if not definitely achieved.

Wednesday, September 13.

Excursion (with Section K) to the works of the Timber Fireproofing Co., Ltd., Market Bosworth, near Nuneaton.

SECTION L.—EDUCATIONAL SCIENCE.

Thursday, September 7.

Training for Business and Administration :—

Principal H. Stewart, C.M.G., D.S.O.—*University training for business* (10.0).

(1) A function of University to train mind ; not a function to turn out ready-made business man any more than complete engineer. Practical training essential ; given outside, and preferably after, University course.

(2) Two types of training : (i) course without commerce bias ; (ii) course with commerce bias. Opinion divided as to which is more suitable. Many prefer former, regarding manner of training more important than subject.

(3) Limitations. University cannot provide the fundamental personal qualities essential : those of character, not intellect. Prolonged academic work unsuitable. University trainees more likely to develop established business than build up from nothing.

(4) Advantages. Training to think, grasp principles and essentials. This is the primary advantage. Secondary advantages are : (i) training in use of language ; (ii) moulding of character in microcosm of student life. Cultural interests and athletic prowess less relevant. Given the fundamental qualities, University education valuable for higher positions. Graduates in early business career behind other recruits in technical knowledge, afterwards definitely superior in judgment, vision, executive power.

(5) Changed attitude towards apprenticeship on probation at small salary, as in engineering. Training after entering business. Difficulty of, and case for, preferential treatment.

(6) University only one of several avenues, but of growing importance. Increasing necessity and demand for well-trained minds in business.

Mr. T. Kingdom.—*Secondary school training for business* (10.15).

General aims of secondary school education in preparation for life as well as livelihood—cultivation of qualities as well as inculcation of knowledge.

The large increase in the numbers receiving secondary education means that far more pupils must go into business. Ought this to mean any modification in our methods and curriculum ? Employers seem to be satisfied on the whole with the product they get. The School Certificate gives a good general grounding in a variety of subjects. It should not be confused with Matriculation. Roughly, only half the pupils in secondary schools secure the School Certificate, and many pupils well suited for business cannot pass it. Value of headmaster's recommendation. Danger of the black-coated professions securing the pick of the brains.

Qualities desirable in business, such as method, tidiness, courtesy, adaptability, resourcefulness, initiative, and leadership, can only be developed if pupils stay longer. A year's course for business pupils of 16 plus, whether they have passed the School Certificate or not, is very desirable. Possible co-operation with technical colleges. Suggested curriculum to include modern languages, economics, manual work, and perhaps shorthand.

Mr. E. I. Lewis.—*The requirements of a business career* (10.30).

For many years secondary schools have been preparing boys for certain professions and branches of industrial life, particularly in science and

languages. To make further provision for an educational type will therefore violate no principle. Any subject or any number of subjects can be taught in a specialised manner, and almost any one of them can be entirely educative. The study of industry and commerce is no exception. The schools profess to prepare boys for work and leisure. Since industry and commerce touch nearly everyone directly or indirectly, and everyone by his franchise can influence their course, a well-educated man to-day should know enough of them to understand at least what his daily journal seeks, for the country's sake, to teach him. The boy who enters industry or commerce nowadays goes to an extremely complicated and highly departmentalised institution. Leaders of industry of the future must inevitably be more cultivated in business matters. To prevent an early narrowness of view, and to promote the growth of wide interests within business concerns—to provide a bridge from school life to business life—a young man, before he enters the office or the works, should have studied, in an educational manner, some of the more pressing problems of business life and organisation. The paper indicates briefly the scope and the principles upon which to construct such a course.

Mr. F. W. Lawe.—*Selection and training of university men in a department store* (10.45).

The actual process of the selection and training of University men in one firm is examined, and some light thrown on the general problems of transition and adjustment.

Two schemes of selection and training, covering eleven years in all, have been tried by the Department Store in question. The first, which ran for seven years, was characterised by liberality of outlook in selection and light-handed control in training. The training course consisted, as in many firms, of a sojourn in each of the important departments. The trainees acquired their knowledge successfully or otherwise in accordance with their individual characters. The results were not encouraging. Of eleven selected, five remained at the end of a seven-year period, and only three at the end of eleven years. All three remaining fully justified their choice. The second scheme, which superseded the first, has been in action only four years. Seven selections have been made. None have left. The three first selections are already in responsible posts and promise well. The characteristics of the second scheme are (*a*) the limitation of entrants to First Class or good Second Class Honours men; (*b*) the introduction into the training course of methods specially devised for rapid and accurate learning; and a tutorial system intended to develop initiative and to foster the adjustment of personality.

Mr. G. C. Wickins.—*Training of the Post Office counter staff* (11.0).

Introduction.—The detailed description in this paper applies to the counter staff in the London Postal Service.

Recruitment.—The male Probationary Counter Clerks are recruited from Boy Messengers. The female Probationary Counter Clerks are recruited in two ways: (*a*) open competition; (*b*) limited competition. The 'limited' candidates enter the service as Girl Probationers.

Training.—(*a*) *General.*—The fundamental principles underlying the scheme of training are that it should be of a practical nature, and that the instruction should be so arranged as to develop the interest of the students in their own work, and to enable them to understand the relation which that work bears to other Post Office activities.

(*b*) *Classes.*—Separate classes are arranged for male and female students, and they are divided into :

Junior Class for new entrants—course, twenty weeks, half-day.

Senior Class for counter clerks who are working in post offices, but are not yet qualified in the more important counter duties—two weeks' course.

Supervising Class for counter clerks who are about to substitute on supervising duties—one week course.

(*c*) *Instructors.*—The instructors for the junior and senior classes are senior counter clerks. Supervising officers take the supervising classes.

(*d*) *Junior Class.*—(i) *Syllabus.*—The Standard Time Table—Appendix I —shows the subjects taught, and the order in which the lectures are given.

(ii) *Lectures.*—Summaries of the subjects dealt with in the lecture are dictated at intervals to the students after the instructor has explained the subjects. Accurate summaries are an important feature of the work.

(iii) *Practical work.*—The students act in turn as counter clerk and 'member of the public,' and each transaction is completed in the same manner as in actual business.

(iv) *Tests.*—Written, practical, and recapitulative practical tests are included.

(v) *Completion of training.*—The training is completed at a post office counter.

(*e*) *Senior Class.*—Co-operation and discussion between instructor and students are encouraged. A précis of each lecture is distributed, on which students make their own notes.

(*f*) *Supervising Class.*—The main features are lectures by heads of departments on general questions of supervision, and practical instruction in Post Office counter accounts.

Discussion (11.15). (Principal J. Cameron Smail, O.B.E.)

Report of Committee on *Science Teaching in Adult Education* (Prof. J. L. Myres, F.B.A. ; Dr. C. H. Desch, F.R.S. ; Mr. A. S. Firth ; Miss H. Masters ; Mr. R. J. Howrie ; Prof. R. Peers ; Mr. G. C. Hickson) (11.45).

Discussion.

Afternoon.

Visit to Loughborough College.

Friday, September 8.

Education for the Industries of the East Midlands :—

Dr. P. W. Bryan.—*Geographical and general introduction* (10.0).

Mr. H. Salt.—*The boot and shoe industry* (10.20).

Five problems have to be considered :

(1) The change in the conduct of the industry from home to factory work.

(2) The change from hand operations to almost identical operations done by machines.
(3) The lack of uniformity in the industry's raw materials.
(4) The standard of 'studentship.'
(5) The lack of suitable books of reference, and the means adopted up to the present to solve this.

Mr. JOHN CHAMBERLAIN.—*The hosiery industry* (10.35).

Education for the hosiery industry was originally of a technological character, and the subject was treated in a very general manner, but, as the trade developed, it was found necessary to form grouped courses of instruction for the training of persons occupying functional positions, as follows: (1) General hosiery course. (2) Course for designers and makers-up. (3) Dyeing and finishing course. (4) Administration and salesmanship.

Course (1) is intended to give the student a clear idea of trade processes and machinery, as well as the sciences underlying the industry. Yarn testing and fabric analysis form part of this course. Both full-time and part-time courses are available for this course and courses (2) and (3). Course (2) is based essentially on a knowledge of art, especially dress design, but includes technical subjects, such as the theory of knitting, stitch effects, patterning mechanisms and fabric production. Course (3) has a bias towards chemistry and provides instruction for the dyeing of all fibres used in knit-wear. Analysis of reagents used and testing of dyed materials is specially emphasised. Finishing processes for knit-wear are included in the course. Course (4) is as yet in the experimental stage, but includes a study of business methods, commercial and industrial administration, economics, salesmanship and modern languages.

Dr. H. SCHOFIELD, M.B.E.—*An experiment in education—the Loughborough scheme of engineering training on production* (10.50).

Great controversy has always ranged around the subject of the best scheme for the training of the engineer, but all seem agreed that practical instruction is essential.

It is growing increasingly difficult to secure an all-round training. Mass-production methods in engineering have come to stay, and the all-round kind of experience that the old apprentice received is no longer available. On the practical side the best boy tends to have the least chance. There is little connection between the offices of the firm and the works, and promotion inevitably seems to be more open to a bright youth in the office than for an equally clever boy in the foundry or the machine shop. On the academic side there is a great tendency to grow stale. University syllabuses tend to govern curricula, and these concern themselves with the mathematical and physical sections of the work only, taking little account of management, with all its problems, and the technique of selling goods.

The so-called engineering workshops of the modern University or Technical College are laboratories rather than workshops, and gifts to Technical Institutions are often made from plant no longer required for modern productive industry. Depreciation is still held to be a governing factor, rather than regard being paid to considerations of obsolescence.

To overcome these difficulties several schemes have been tried. The productive college first came into being in America, and in this country it has been very highly developed at Loughborough. The University lecture rooms and laboratories exist side by side with the productive workshops of the commercial engineering firm, and in one and the same set of buildings,

under the same control, using a week-in and week-out system, the student in a five-year course experiences all sections of productive output, from the foundry to the drawing office, and from the machining and fitting shops to the tool room. He is brought up against estimating, costing, and selling. The exercise no longer exists, and the student is engaged in interesting productive work throughout his whole course.

Mr. J. R. Bond, M.B.E.—*Agriculture* (11.5).

Mr. W. A. Brockington, C.B.E.—*Summation* (11.20).

Discussion (11.35).

Report of Committee on *The teaching of science, with special reference to biology* (Dr. Lilian J. Clarke; Dr. E. L. Hirst; Mr. G. W. Olive; Sir F. Gowland Hopkins, Pres.R.S.; Dr. W. W. Vaughan) (12.0).

Discussion.

Afternoon.

Visit to Rugby School and Rugby Day Continuation School.

Monday, September 11.

Joint Session with Section J (Psychology) on *The predictive value of school examinations and psychological tests*:—

Prof. C. W. Valentine.—*The unreliability of entrance examinations to secondary schools and the awarding of university scholarships* (10.0).

Dr. D. W. Oates.—*Some factors in scholastic ability and their predictive value for secondary education* (10.15).

(1) Why predictive values are low. The implied assumption that the criterion is non-variable and represents the ideal. The distinction between ability and capacity.

(2) The need for a sharper definition of what the secondary school demands. Recent evidence of the importance of specific abilities in the secondary school. 'Success in the various subjects depends more upon specific abilities than upon general capacity.'

(3) The 'snapshot' impression of a single examination, even with the best examination technique, may present a distorted and badly weighted index of a pupil's normal achievement and power. The discrepancy between the entrance examination result and subsequent achievement is not necessarily due to faulty measures of achievement, but may be the natural result of other factors.

(4) The results of investigations of the factors in scholastic ability. The importance of some traits which we can crudely describe but for which we have at present no tests that are even approximately objective. The bearing of certain personality factors other than intelligence upon academic success.

(5) The predictive value of a written examination, intelligence test, head-teachers' estimates, and ratings and tests for temperament qualities as revealed by correlation with subsequent secondary school achievement.

Mr. F. Barraclough.—*The reliability of entrance examinations to secondary schools* (10.30).

In recent years local education authorities have paid much attention to the syllabuses for scholarship entrance examinations, but in many cases a corresponding lack of attention to the machinery of the examination has vitiated their efforts.

School records and the position of children in non-provided schools are matters requiring further research.

In making a comparison between the results of scholarship entrance examinations and school certificate examinations the methods of analysis of variance enable the investigator to test the significance of his results.

The work of Prof. Valentine regarding the predictive value of scholarship entrance examinations revealed the need for additional research, and the results of an investigation conducted in 'non-Valentine' areas are given. The predictive value of intelligence tests is also discussed.

Mr. F. Sandon.—*Difficulties in using entrance examinations, intelligence tests and school results for comparative purposes* (10.45).

Prediction is a question in probabilities, and our estimate of a, the ability to profit by education at a secondary school, depends on correct statistical procedure. No test, by reason of various kinds of variability, will be perfect, and any test will only correlate to some degree with the criterion. Even if we have a theoretical correlation table with r, between mark and criterion, as $0 \cdot 85$, in the top one-fifteenth two-fifths of the selection should not be there and the correlation for selected candidates would be computed at $0 \cdot 3$. This illustrates a principle of Karl Pearson that examination statisticians have apparently overlooked. Selection modifies means, standard deviations and correlation coefficients. In an observed case a correlation of $0 \cdot 67$ on feebly selected material was by more and more stringent selection reduced through values of $0 \cdot 07$ and $-0 \cdot 16$ to $-0 \cdot 93$. The farther we get away from the measure of the selection the less will be the effect on the correlation of correlated measures—the other test will always tend to be the better. A correlation coefficient between two measures should not be given *in vacuo*; the material studied should be revealed and special study made of possible selection effects.

Other statistical and allied difficulties are referred to and some suggestions submitted.

Prof. J. Drever.—*The comparative reliability of examinations and tests respectively* (11.0).

Examination marks are unreliable from two points of view. In the first place one and the same examination paper, it is well known, may be differently assessed by different examiners, and even by the same examiner at different times. This defect might to some extent be removed by objective methods of assessment. In the second place school examinations at best have been shown to have an extremely low correlation with University success even in the same subject. The causes of the unreliability in this case would appear to be very complex. The first type of unreliability ought not to be present to any considerable extent in the case of intelligence tests, and the second is certainly not present in the same degree.

Miss A. B. Dale.—*Tests and entrance examinations as predictive of academic success among university women students* (11.15).

During the past seven years a comparison has been made between the intelligence test scores of students of Newnham College, Cambridge, and their performances in academic examinations, the total number of students dealt with being about 530. Students were tested during their first term at Cambridge and again later in their University career. Records were kept of their performances in entrance or scholarship examinations and in their tripos or other academic examinations taken at the end of each year of their course.

The results appear to show that success in advanced and highly specialised academic work depends to a considerable extent on factors other than that measured by intelligence tests, although the influence of this general factor varies in different academic subjects.

Performance in entrance or scholarship examination differs markedly from that in the final examination taken 3½ years later in about 14 per cent. of the cases considered. A special study of these cases shows to what extent a truer forecast of success would have been obtained by combining an intelligence test with the academic papers of the entrance examination.

Mr. E. Farmer.—*The predictive value of examinations and psychological tests in skilled occupations* (11.30).

Discussion (11.45).

Afternoon.

Symposium on *The cultural value of science in adult education* :—

Sir Richard Gregory, Bart., F.R.S. (5.30).

When the Workers' Educational Association was founded thirty years ago, its deliberate intention was to arouse among the workers greater interest in higher education, particularly in relation to subjects of a non-utilitarian character. It represented the view that, in the training of citizens, opportunities for general culture were needed as well as facilities for technical education. There was to be a broad highway to realms of intellectual delight in literature, history and art, as well as in natural science, and the education was to touch the heart and imagination independently of its industrial or commercial contacts.

The cultural value of science in adult education is thus no new subject, but it cannot be said that any clear principles of promoting this value have yet emerged from any educational organisation.

When science is taught, not as an aid to a vocation, but as part of the training of a modern citizen, it may be said to have a cultural value. Attention should, therefore, be given to the influence of scientific discovery and its applications upon social and economic life and thought. Science rightly conceived is modern humanism in the fullest sense. Even if the humanities are understood to mean letters, history and art, there should be no conflict between these studies and natural knowledge. It should be understood that the object of teaching science to general students in adult classes is not to produce specialists but to create in the rank and file appreciation for what is good and needful for intelligent citizenship.

Prof. W. J. Pugh.—*Geography and geology* (5.45).

Prof. W. B. Brierley.—*Natural Science* (*zoology, botany*) (6.0).

Consideration of this question depends on one's idea of the meaning of the word 'culture.' To the author it means an integration of knowledge and experience which helps an individual to lead a reasonably full and free intellectual and emotional life and fits him to play a contributing part in the social community; in short, an orientation towards life which makes for personal happiness and social usefulness. Cultural values are traditionally ascribed to particular subjects but, in fact, cultural values are not inherent in any subject, but derive from the method of treatment and the personal relationship to a subject. There are few, if any, subjects whose study is not of potential cultural value, but the traditional methods of approach often lead only to the accumulation of information unrelated to life as a whole. To possess cultural value a subject must be regarded not as an isolated department of pure knowledge but as an integral part of human life and social welfare, and its pedagogy must have this orientation. The study of biology (zoology and botany) by reason of its methodology of observation, experiment, deduction and generalisation, together with its techniques of recording, can be made to yield ample scope for the development of an individual's sensory, emotional, and intellectual life. By reason of its subject material, which is the basis of all human development and social structure, it can be made to induce appreciation of fundamental principles of life and civilisation.

Dr. Allan Ferguson.—*Chemistry and physical science* (6.15).

Prof. J. L. Myres, F.B.A.—*The general educational problem* (6.30).

Education, as a preparation for life, approaches its task in different ways and by appropriate methods, according to the life to be lived, and the presupposed experience of the pupil. In adult education, the student's experience is wide but ill-co-ordinated; his faculties though mature, are ill-trained; he is less receptive of systematic instruction, more appreciative of theoretical assistance applied to concrete episodic problems. His approach to all enquiry,—'scientific' in the popular sense, or other,—is rather that of explorer and pioneer, than of pupil or disciple. Collaborative apprenticeship, however, has been his normal introduction to technical skill; and usually he understands what team-work means, even when he is not by disposition suited to it. These considerations affect the teaching, no less than the learning, of adult students. Historical and economic studies have had their vogue mainly because they have been presented to adult classes as remedies for social inconveniences in daily experience. Comparative indifference to the natural sciences results less from intrinsic abstruseness, than from the failure of academic exponents, laboratory-trained themselves, to appreciate the necessity of beginning with what the student practically knows and can do, with the simple means at his disposal and chiefly with his own trained eye and skilled hand.

Dr. Vaughan Cornish.—*The æsthetic aspect* (6.45).

Sir Josiah Stamp, G.B.E.—*Summation.*

Tuesday, September 12.

Presidential Address by Mr. J. L. Holland on *The development of the national system of education* (10.0). (See p. 219.)

RESEARCH WORK BY TEACHERS AND SCHOOLS :—

Dr. A. H. SMITH.—*Field-names* (11.10).

Dr. L. DUDLEY STAMP.—*Some types of local survey* (11.30).

This paper describes an attempt to apply a simplified form of the regional survey method on a nation-wide basis. Starting with the assumption that a fundamental aim of juvenile education is to provide an adequate preparation for adult life, an intensive study of the home region and of the local environment is used as a starting point for a training in citizenship by awakening an appreciation of the significance and relative importance of the facts of local geography, history, and economics. Several bodies exist to encourage regional survey as an educational method and amongst them was the Regional Survey Committee of the Geographical Association. The author, on his resignation from the Indian Educational Service in 1926, became Secretary of this Committee and it was soon apparent that only the larger or better-equipped schools could, except with specially enthusiastic leadership, organise a complete local survey. A search was made for a simplified form which could be undertaken by the smallest rural schools—even single-teacher schools—but which would carry the advantage of the method and would, at the same time, yield results of permanent value. By a magnificent pioneer effort, Mr. J. L. Holland, Director of Education for Northamptonshire, assisted by Dr. E. E. Field, showed how the rural schools of a county could effectively undertake a survey of the uses of land, each school studying its own parish. With this example before them, the Land Utilisation Survey of Britain was formed in October 1930, with the help of a grant from the Rockefeller Fund of the London School of Economics. The Survey was careful to remain an independent body and all work has been carried out on a voluntary basis, though the approval of the Board of Education, Scottish Education Department, County Councils Association, and many other bodies was first obtained. The Survey was organised on a county basis, England, mainly in 1931 ; Wales and Scotland mainly in 1932. In seventy of the ninety-three administrative counties the Director of Education has been the county organiser. It is estimated that 10,000 schools and 200,000 children have taken part in the study of the 22,000 sheets of the 6-in. ordnance map which are involved. The methods followed are described ; independent opinions and estimates of the value of the work are given. A number of the maps on the scale of 1 inch to 1 mile, now being issued by the Ordnance Survey as a result of the Survey, are mentioned. The results of the Land Utilisation Survey further illustrate in a remarkable way the controlling influence on the progress of educational experiments exercised by the County Education Committees.

Mr. A. S. MCWILLIAM.—*A research in agriculture at Lady Manners School, Bakewell* (11.50).

This paper is an account of some of the field experiments carried out by the boys and girls in connection with the biology course. The experiments are arranged in collaboration with the Rothamsted Experimental Station.

The experiments on meadow hay consist of, first, an eight plot manurial test which gives significant results for the complete manure, all the other treatments containing nitrogen and for potash in the presence of nitrogen. The second one demonstrates the importance of the degree of solubility of phosphatic fertilisers ; and the third is a two years' trial to compare the action and manurial residues of dung and complete artificials.

The experiments on arable crops are (1) the comparison of nitrogenous fertilisers on potatoes in which nitrogen in all the forms tried gave significant results, but the differences between the various forms of nitrogen were not significant, and (2) a rotation experiment on the eight plot system which brings out some overall effects. The size of the plot varies from 1/120 to 1/200 acre each; the treatments are replicated and randomised. The standard errors compare favourably with those obtained at research centres where larger plots are used.

Miss J. K. Jones.—*A village survey* (12.10).

A short account is given of the work done in two small Oxfordshire village schools over a period of years under the guidance of Miss C. V. Butler, M.A., who, with Miss C. A. Simpson, wrote the Board of Education Pamphlet No. 61 on 'Village Survey Making—an Oxfordshire Experiment.'

One of the schools, Lower Heyford, is in a 'compact' village, in the centre of the county, on the Cherwell, typically a valley village; and this survey is compared with that of Idbury and Fifield, on the extreme west of the county, 600 ft. above sea-level, on one of the Cotswold slopes.

The points of comparison will be:

(1) *Geological formation*, involving types of water supply, buildings, boundaries, crops, and fields with their names.
(2) *Economic life* of the inhabitants; local industries, existing and extinct; markets.
(3) *Illustrations of social history*.—Enclosures and commons, tithe barns, pounds, turnpikes, manorial rights.
(4) *Local customs*; Folk lore, weather lore, children's games.
(5) *Nature study*; Trees.
(6) *Method*. (*a*) Utilisation of children and the effect on ordinary school work.
(*b*) Utilisation of parents—neighbours and old scholars.
(7) *Limitations and value*. (*a*) As 'finding out' with some real contribution to knowledge; (*b*) as an educational method.

Discussion (12.30).

SECTION M.—AGRICULTURE.

Thursday, September 7.

Presidential Address by Dr. A. Lauder on *Chemistry and Agriculture* (10.0). (See p. 243.)

Discussion on *Some sociological aspects of agriculture*:—

Mr. R. R. Enfield.—*What is our objective in agriculture: high production, high employment or high standard of living?* (11.0).

The objective of a higher standard of living. Its relation to general economic progress. Economic factors affecting the problem of increasing agricultural production and employment. The trend towards economic nationalism. The country's balance of payments. Sociological factors. How can these be measured? Their relation to economic factors. Examples of other countries. Technical questions involved. The effect of

modern technique on employment and production. Questions of procedure. Conclusion.

Prof. A. W. Ashby.—*Technical and economic efficiency and some social results* (11.30).

Discussion (12.0).

Afternoon.

Excursion to the Robert Bakewell Memorial and the Midland Agricultural College.

Friday, September 8.

Discussion on *Land drainage* :—

(1) Larger Waterways.

Mr. A. T. A. Dobson, C.V.O., C.B.E.—*The law of land drainage; arterial drainage* (10.0).

A brief account is given of the trend and object of land drainage legislation prior to 1930, when a new and comprehensive Act was passed repealing all previous enactments, and providing for the constitution of a new class of land drainage authority.

The more important of the powers conferred by this latter Act are shortly described, and some account is given of the progress that has already been made and is likely to be made in the future by the new authorities which have been set up under that Act, in dealing with the task before them, and in organising the drainage system of the districts for which they are responsible.

The nature of the operations which urgently require to be carried out on the main rivers of England and Wales is referred to, and an attempt is made to show that powers now exist for the first time under the Land Drainage Act, 1930, whereby every watercourse from the farm ditch to the great arterial or estuarial river, can be maintained in a reasonably effective manner with the financial resources provided under the Act.

Discussion. (Mr. W. Haile.)

(2) Field Drains.

Mr. H. H. Nicholson (10.30) :—

(*a*) *A general survey of the position on farms.*

The area of land requiring field drainage varies enormously from one part of the country to another, depending on such factors as physiography, geological formation, the main drainage channels, the type and maintenance of previous drainage operations. Tile draining and mole draining are still practised, the former to a diminished extent. Ditching and the cleaning of watercourses are still carried out with effect, but these important links between the field drains and the main water-ways are being increasingly neglected.

(*b*) *Drainage investigations at Cambridge.*

The field moisture profile of the soil and its variations throughout the year have been studied particularly on heavy land, in conjunction with the incidence of rain and the performance of drain outfalls. The mode of

operation of mole drains, their shape and the changes which take place with age, have been examined. Observations have been made on the permeability of the soil in the field and its seasonal variations.

Dr. H. Janert.—*Drainage investigations on the Continent* (11.10).

Many soils in Germany require amelioration to make farming profitable and to intensify cropping to the level necessary to provide home-grown foodstuffs for the whole population. To this end the German states have always paid careful attention to land amelioration work, and a special organisation was set up to lead and to supervise amelioration generally and drainage in particular.

Land amelioration boards exist in all the German states and possess a large staff of trained amelioration experts, called *Kulturtechniker*. The duties of these experts are very diversified and include irrigation, cultivation of moor and marsh land, and particularly drainage.

It is now fully recognised that efficient drainage can only be expected if the water and soil conditions are carefully investigated and taken into account. The soil conditions are of particular importance in determining the appropriate drain depth and separation. Before modern methods of soil investigation were introduced into drainage practice, the soil conditions were estimated simply by practical experience. This was found to be most unreliable, and it has been shown by field and laboratory researches that close relations exist between the results of certain laboratory tests and the response of a soil to drainage.

These relations apply only to tile drainage, which, however, becomes uneconomic in the case of the extremely heavy soils. In some of these mole draining can be successfully employed, but in others the moles do not hold, and some internal support must be provided for the mole channels. A new method for this purpose is proposed and described.

Mr. J. H. Blackaby.—*Drainage machinery* (*with a note on the measurement of outflow*) (11.35).

Mole draining requires considerable power, a variation from 7 to 23 drawbar horse power being shown in the records of tractor working. The methods of providing this power are a team of horses, a portable winch operated by hand, horse or low-powered engine, steam cable engines, direct tractor haulage and tractor cable haulage. Each has advantages and limitations. Mole ploughs in this country are essentially of simple form ; there are points in construction which make for good work. Continental machines have been elaborated for various purposes. Mole draining can be done very cheaply. Mole drains have lasted fifty years, shallow tractor-drawn mole drains have worked well for five or six years.

Tile drainage is comparatively expensive by reason of the hand labour involved. Various forms of excavator have been developed to minimise this and speed up the work. Ditch cleaning has also been mechanised. For arterial watercourses, excavators of varying size of the drag-line or grab type are used.

A meter for measuring drainage outflow has been designed and tried out in the field by the Institute for Research in Agricultural Engineering. This meter is automatic and self-recording and can deal with rates of flow from zero up to 4 gallons per minute.

Discussion (12.0).

Saturday, September 9.

Excursion to open fields, Laxton. Paper during excursion :—

Mr. C. S. Orwin.—*The open field parish of Laxton.*

Laxton has an unique interest for the agriculturist and the economic historian in that it is the last survivor of the open field parishes, and it remains the only place where the manorial system can be studied as a living organism.

The population is still concentrated in the village, with the farm buildings and crofts behind each dwelling-house. The demesne lands, all of them ancient inclosures, extend along one side of the parish. The common, with its cow-gates attached to certain of the holdings, is still in being. The plough land of the parish is still divided into three great fields, over which are scattered the holdings of the tenants, and they are farmed strictly on the old three-course rotation—winter corn, spring corn, fallow. Stubbles and the fallow field are still grazed in common by the livestock of the tenants. The Court Leet is still summoned by the Bailiff, and the jury is sworn by the Steward of the Manor. A Pinder is appointed to control the common grazing, and to impound straying or unauthorised stock in the parish pinfold. The jury inspects the state of cultivation and fines delinquents.

Laxton has belonged to the family of Earl Manvers for the last three hundred years. It is an historical monument of the first importance, for it demonstrates the manorial system in a way which no written description can.

Monday, September 11.

Discussion on *Grazing problems* :—

Alderman P. F. Astill.—*Grazing in the Midlands* (10.0).

The grazing of the rich pastures of the Midland area consists of feeding animals for a comparatively short time till they are fit to butcher. The feeder has to consider what type is most suitable for his pastures, and at what weight and age the animal commands the best price. He must estimate the number his farm will carry, and have a proportion of his stock ready to market as soon as his pastures have reached their maximum growth.

The greatest factor in producing these renowned pastures has been the management.

Their richness or strength has unfitted them for feeding the younger animal the public now demands and presents an unsolved difficulty which merits most careful inquiry. The consumer's demand for a small and tender joint is much easier to meet in the production of mutton and lamb than in beef.

The rearing of the right type of store is increasingly important and there are good reasons to expect an early improvement.

The increase of the grass acreage has caused an unequal production of both beef and mutton, with great fluctuations in value which tend, in the period of short supply, to limit the demand for home-produced meat.

Mr. Martin G. Jones.—*The art of grazing and its effect on the sward* (10.30).

Pasture is a perennial crop, and the art of grazing resolves itself into two aspects, viz. the maximum production from the sward in any particular

season and the maximum benefit to that sward for production in future years.

Both aspects are closely bound up with the botanical nature of the sward, and therefore any treatment that favours the best plants will improve the sward for future years, whilst any treatment that favours undesirable plants will cause a deterioration.

Pastures generally contain a number of different species and strains of plants which are in continual competition with one another, and the experiments to be described have shown how the grazier by adjusting the rate of stocking at various times of the year does unconsciously determine which of the botanical constituents in his sward shall predominate. Starting with an uniform area of pasture it has been possible to convert one portion into a clover-dominant sward, whilst a corresponding portion has been converted into a grass-dominant sward. The grassy sward has been further divided, causing *ryegrass* to become dominant over *cocksfoot* in one section, whilst the adjoining section has *cocksfoot* as the dominant plant.

Mr. W. Davies.—*The biotic factor : lessons from Australian and New Zealand grasslands* (11.0).

Grassland is an unstable vegetation complex, often a direct biotic complex which depends upon the action of grazing animals for its maintenance as grassland. The problems of pastures established by man in place of forest are compared with those of semi-arid (steppe and savannah) regions. The influence upon the pasture complex of contrasting management and different types of stock are examined, as for example, the control of grazing by domestic live stock and uncontrolled grazing by wild animals, as rabbits, kangaroo and other organisms.

The principles of pasture maintenance and pasture improvement are briefly considered from the several view points of (1) species and strains ; (2) soil fertility ; and (3) management.

(1) Desirable attributes in herbage plants ; the value of knowing source of origin in purchasing pasture seeds ; seed certification in relation to herbage plants—tendencies in New Zealand, Australia and Britain.

(2) The improvement of soil fertility. The value of pasture legumes as soil improvers and as payable pre-crops : lessons based on Australian experience. Pasture plants classified according to the demands made by them upon soil fertility.

(3) Grazing technique in relationship to botanical composition. The influence upon the sward of differential grazing : (*a*) heavy continuous ; (*b*) heavy intermittent ; (*c*) overstocking and understocking ; (*d*) haphazard and controlled grazing. The reactions of individual species and causes of depletion in semi-arid grazings.

Mr. A. Bridges.—*Some economic aspects of grassland* (11.30).

Since the war the problem of grassland has received considerably more attention than formerly. . In rather less than twelve years a vast amount of scientific knowledge has been gained in relation to the management of grass and placed at the disposal of farmers if they have the wish and the need to use it. The reason which has prompted this attack on the grassland question is the large increase in the area under grass since the war. A peculiar feature of the post-war situation is the large increase in the area of rough grazings. The increase in the area of grass is the result of two

tendencies. First, it is the complement to the increase in livestock farming; and, secondly, the result of a desire to curtail expenditure on unprofitable arable land during the depression. The improvement of this latter class of land may not be desirable at present.

The improvement of old grassland in poor condition can be financially successful, as Mr. Bligh's experiences show, yet it makes little headway on a national scale. There are certain factors limiting activity in improving poor grassland: (1) the alternative of an increased output from better class grassland; (2) the laying down of arable land to grass; (3) the special function of poor grassland in systems of farming; (4) the speculative nature of the investment.

In the subject of the economics of grass and hay versus purchased foods as a management question it appears that grass and hay are much cheaper to produce than most purchased foods. Yet purchased foods play a special part on grassland farms. For their reliability and convenience, as compared with an uncertain and variable supply of food from grass, farmers are prepared to pay a higher price. Scientists must remove the uncertainties of grass as a food supply.

Discussion (12.0).

Afternoon.

Visit to the Market Harborough grazing area.

Tuesday, September 12.

Discussion on *Milk production and distribution in relation to nutrition and disease*:—

Prof. T. J. Mackie.—*The milk supplies of the country in relation to the public health* (10.0).

Introductory: milk in human diet; milk as a vehicle of infection—the hygienic problem; consumption of milk in this country; need for a higher standard of purity.

Factors that have influenced the condition of the general milk supplies—the distribution of milk to the urban communities—transportation and retailing of milk.

Bacterial contamination: sources—milk as a bacterial growth-medium—hygienic and economic aspects—methods of dairying and distribution.

Milk-borne infection: bovine tuberculosis and human infection by the bovine type of tubercle bacillus—prevalence of bovine disease and of tubercle bacilli in market milk—human mortality and morbidity due to bovine-type infection; other infections and their sources; bovine contagious abortion and undulant fever ('abortus-fever') of the human subject—prevalence of *Bacillus abortus* in market milk.

The control of milk-borne tuberculosis; 'open' tuberculosis of cattle—tuberculosis detected by tuberculin reaction—existing legislation in control of disease—eradication of the disease from dairy herds, methods, achievements, and future progress—the position of the individual farmer; designated milks.

Disinfection of the ordinary market milk—pasteurisation: question of its efficacy—methods—need for control—effect on nutritive qualities—question of compulsory pasteurisation.

Immediate measures to ensure safe milk supplies.

Mr. W. Godden and Dr. J. Blackwood.—*The nutritional aspect* (10.30).

Dr. N. C. Wright.—*Some implications of compulsory pasteurisation* (10.50).

Apart from the relation of pasteurisation to the reduction of milk-borne disease and to the nutritive value of milk, certain other factors must be taken into account in deciding whether a policy of compulsory pasteurisation for city milk supplies is justifiable. Such factors include the effect of compulsory pasteurisation on the producer-retailer and the small distributor; the influence of pasteurisation on the production of clean milk and on the eradication of bovine disease; its effect on wholesale and retail milk prices; and, finally, the expediency of applying an element of positive compulsion to the artificial treatment of such a widely consumed foodstuff as milk. These factors are discussed in the present communication.

Mr. Ben Davies.—*The problem from the point of view of the dairy industry* (11.10).

Prof. G. S. Wilson.—*The necessity for a safe milk supply* (11.30).

Milk is a valuable food, and so far as its nutritive properties are concerned it is not an expensive food. Its importance in infant feeding, its power to stimulate the growth of under-nourished school children, and its value in the treatment of disease, amply justify for it a very special place in the human dietary. Unfortunately, however, owing to the fact that it is particularly liable to become infected, and that it furnishes an admirable medium for the multiplication of many types of pathogenic bacteria, its use in the raw state is bound to be accompanied by a certain amount of danger to the human population. While the production of clean milk from healthy animals may diminish this risk to some extent, it can never entirely eliminate it. To do this, the only satisfactory measure at the moment is some form of heat treatment that will destroy all pathogenic bacteria, while interfering to a minimal degree with the nutritive value of the milk.

Discussion (11.50). (Dr. H. D. Kay, Miss Olga Nethersole.)

EVENING DISCOURSES.

FIRST EVENING DISCOURSE

FRIDAY, SEPTEMBER 8, 1933.

MUST SCIENCE RUIN ECONOMIC PROGRESS ?[1]

BY

SIR JOSIAH STAMP, G.B.E.

ECONOMIC progress is the orderly assimilation of innovation into the general standard of life. It usually connotes a widespread sharing of new benefits, but is by no means inconsistent with some degree of uneven distribution of wealth or income, for in a non-socialistic community some disparity generally raises the standard of life of the mass to a point higher than it would be under a forced equality of distribution of wealth, the envies caused by disparity notwithstanding. The purely material standard in Great Britain was raised fourfold during the nineteenth century, and probably rather more in the United States. If we take into account also length of life and proportion of leisure, the increase is much greater. The improvement arises only to a very small extent in changes in the average innate capacity of man, not co-operant with, or parasitic upon, his environment. It is almost all due to innovation in social activity (including social education and the reactions of economic betterment upon physical and mental ability). The greater part of the innovation is scientific innovation—in physics, engineering and public health ; but a not inconsiderable part falls outside these categories, and belongs to the non-physical section—better ideas about money, more social confidence in banking and credit, improved political and social security and legal frameworks for the better production and diffusion of wealth. The elaboration of these factors depends partly on intellectual prevision and invention, but mainly upon average moral standards and calibre of character, since many political schemes, including international co-operation, are impracticable only because of failings in the present standards of human nature.

It is being commonly stated that scientific changes are coming so thick and fast, or are so radical in their nature and implications, that the other factors of social life, the intangibles of credit, the improvements in political and international organisations and ideas, are unequal to the task of absorbing and accommodating them, or else they present new problems which have no counterpart. If changes in social forms and human nature or behaviour cannot possibly be made rapidly enough for the task, then in

[1] For further reports, see *Lecture Recorder*, **3**, 3, Oct. 1933 ; *Nature*, **132**, 3333, p. 429, Sept. 16, 1933.

that sense science may ' ruin ' economic progress, and the world might be better served in the end if scientific innovation were retarded to the maximum rate of social and economic change. Civilisation went through a long period when the limiting factor to progress was the scientific, but is now passing through a stage when the limiting factors are non-scientific. The lack of identity in the *tempo* of change creates new problems, tending to offset scientific advantages, of three types. First, for example, the utilisation for essential or competitive purposes of rare minerals, the need for which becomes general, but the distribution of which is particular and accidental, sets up great political strains, and we have invented no means of adjusting the international effects of accidental monopoly of essential elements. Second, the problem of scope, where the scale of production upon which, for example, a chemical innovation can be made to give its real economic advantages, is a scale inconsistent with the size of markets freely open in a nationalistic world. Here strains are set up in the international machine, and the balance of trade, which may gravely jeopardise economic progress, and dry up the juices of commerce. Third, for example, where the innovation is absorbed most easily for offensive purposes in a military or naval sense, it may create rivalries and changes of balance of power inimical to economic security, and compel new economic sacrifices outweighing the direct economic advantages of peaceful uses. It is open to question whether the innovation of aircraft has yet become, on net balance, economic progress.

Inasmuch as all economic production creates real vested interest in a location or a skill devoted to it, and every scientific innovation alters the centre of gravity of collective demand, every such scientific change disturbs an economic equation. That equation for human life may often be richer ultimately, but the pain or waste of disturbance has to be debited to the gain, before the net balance is progress. For the time being, the balance may be net loss, the price paid for to-morrow. If to-morrow is continually postponed, because it, in its turn, is redisturbed, and the economic to-morrow never comes, it is literally jam yesterday, jam to-morrow, but never jam to-day. Wastes of absorption will be at a minimum in certain conditions, which are related to the wearing life of existing assets and places, and to the rate of flow of new skill into new directions. The orderly absorption of innovation into economic progress, apart from improvements in the non-economic factors of such progress, depends upon two kinds of balance. The first is the balance between two classes of scientific discovery, that which accelerates or makes easier the production of existing economic goods, and that which creates new kinds of economic satisfactions—the derivative and the direct. Let us suppose that in static society a million people are employed making boots, and the gramophone has not been invented. Then let a labour-saving device be invented, such that the same quantity of boots can be made by half the workers, and boots are half the price. Assuming that the demand for boots is quite inelastic, and no more are wanted, there is potential unemployment for half a million people, and the whole population has now reserve unspent purchasing power, saved on cheaper boots. The gramophone is introduced, employing the potentially unemployed, and absorbing the reserve or released purchasing power. The progress of the past hundred years has been essentially of this order, and innovation has enabled purchasing power to be released for new spending—first, upon far *more* of the same article at the reduced price ; second, upon more of other existing goods ; and, third, upon entirely new kinds of satisfaction, bicycles or radio sets. In this connection it must be remembered that an old article may be so transformed in degree as to be equivalent to

a change in kind—the silk stocking and feminine footwear are cases in point. Now even if these two classes of innovation, direct and derivative, are in balance, the process of absorbing them will give rise to economic growing pains and temporary dislocations of capital and employment, but the gains will rapidly outweigh the disadvantages. But when they are not in balance the process is more painful, and the debit to be set against progress very much greater. The introduction of machinery has been for three hundred years accompanied by the same hostile arguments, for the immediate effects in unemployment are much more obvious and human than the countervailing employment given by the released purchasing power, which may occur in some other place or country. Illustrations may be found all the way from Queen Elizabeth's sentiments on stocking-knitting machinery to the Luddite riots, and the eight looms per weaver of to-day. But in the literature of the whole series, nothing can outdo, for detailed economic jeremiad and precise calculation of woe, a contemporary examination of the effect of the introduction of the stage-coach in the middle of the seventeenth century upon the post-horse industry and all that depended upon it. (*In Grand Concern of England*, 1673.)

The argument so far, no doubt, begs the question of the meaning of progress, and assumes that silk stockings and fine shoes represent ' higher ' standard of life than black homespun woollens and rough boots—a doctrine that is not acceptable to Mr. De Valera, for example ; but as we are not entering the field of morals or ethical aims, we are obliged to assume that those objects which are actually the subject of average human desire must be given their economic significance accordingly, and not attempt to solve the larger problem simultaneously. In this sense such a mechanical invention as the totalisator must take its place in ' progress ' at this stage.

The problem of balance, in the direct and the derivative, is not however so simple in practice, for the sum total of the effect of derivative innovations (creating technological unemployment) ought to be balanced by the sum total of direct innovations or increased demand for other products (new and expanded employment). But many direct innovations are not additive, they are substitutional, and destroy the need for old commodities. If combs are made from celluloid, and dishes from papier mâché or pyrex, they will certainly not create a wholly additional demand or employment—there will be a displacement of the old types in metal or bone combs or china dishes. This substitution goes into rival classes of utility also, and a radio set may be a real substitute for a billiard table, and oil may be the enemy of hops, if cheap bus-riding supplants long sittings in public-houses. These substitutions may be gradual enough to be absorbed as a normal feature of progress, but if they are very rapid and coincide with certain other economic disturbances they may be very distressing. By ' normal ' I mean such as can be coped with by the direction of new labour entering industry or new capital spent on renewals, leaving the contractions to take place by natural age attrition without unemployment, or by premature obsolescence—for the moment this is the optimum point of change.

The lack of balance between derivative and direct innovation may be due, of course, to a terrific drive and rapidity in scientific recovery of the industrial type, but it is only fair to say that the excess of one may be due to causes on the economic side. If, for purely monetary reasons, the gold standard, etc., the purchasing power of money is continually increasing through falling prices, and, with the current inability to change the money totals of wages and other costs, real wages are rising, it becomes increasingly possible to substitute innovations of machinery for hand labour, or complex for simple. A change that was not worth making on a balance of old wage

costs against new capital costs in 1923, became well worth making by 1932, and indeed imperative, if any profits were to be preserved. Hence the almost artificial pressure which a rigid monetary system may bring to bear towards the over-rapid application of new methods and creation of unemployment.

The second kind of balance which is vital to economic progress and which may be ruined by over-rapid innovation is that between obsolescence and depreciation. Nearly all scientific advance for economic progress has to be embodied in capital forms to be effective, more and more elaborate, large and costly. The productivity of such apparatus and plant per man involved becomes greater, and, even allowing for the men employed in making the machinery or process, the total satisfaction is continually produced with less and less human effort. Now it used to be said of British machinery that it was made good enough to last for ever and long after it became old-fashioned, whereas American machines were made to be worn out much earlier, and were thus cheaper, but could be immediately replaced by capital assets containing the latest devices. If the period of physical life and fashionable life can be made to correspond, there is greatest economy and security of capital. But if the expensive embodiment of the latest science can be outmoded and superseded long before it is worn out, there is waste of capital, loss of interest, and resultant insecurity of business and investment. The factor of physical safety alone means that each embodiment must be really durable, even if roughly finished, and, therefore, it is impossible wholly to reduce physical life to probable ' obsolescent ' life. In this way an over-rapid series of innovations may mean the scrapping or unprofitability of much excellent capital for very small marginal gains. A responsible socialist community would see each time that the gain was worth while, but competitive individuals have no collective responsibility. Suppose the giant Cunarder attracts a profitable contingent for two years only, when a lucky invention in a new and rival vessel attracts all her passengers at a slightly lower fare. Here is progress in one typical sense, but the small net advantage to be secured by individuals as free-lance *consumers* may be dearly purchased by large dislocations or loss of capital, reacting even upon those same individuals as *producers*.

Now, if the innovation were very striking, and were reflected in working costs, the margin of difference between the old working costs and new working costs may be large enough to pay interest on the new capital employed, and also to amortise the cost of the unrealised life of the asset displaced. A locomotive may have many years of useful life left, but a new type *may* provide a margin by lower working costs not only sufficient to make one adopt it on normal renewal, but also to pay for the premature scrapping of the old type. The majority of modern innovation is, however, of the type which does *not* pay the costs of obsolescence and proceed by orderly and natural physical renewal or substitution. A similar type of argument applies to the capital expenditure generally on a district, which can be amortised over the economic activity of that area, such as a colliery area, but which is wasted if a dislocation occurs by the adoption of some innovation stimulating rival activity in another place. Similar but more poignant considerations apply to obsolescence in human skill and training, more rapid than the ordinary attrition through age retirement can accommodate. Physical capital forms, human vocational training, and centring in geographical areas, are all essential features in the absorption of scientific innovation into economic progress. Each has its *natural* time span, and a narrower span of scientific change is bound to set up large economic debits to be set against the economic credits of the change. A man running a

race might be stopped to be given a new magic cordial which, *after* allowing for the two minutes stoppage, would enable him to finish a minute earlier. But if he is stopped at frequent intervals for other magic cordials, each advantageous by itself, the total period of stoppages would at some point exceed the possible gains of speed during the short undisturbed running periods, and he would finish later at the post, instead of earlier. This is a parallel to the current effects of too rapid disturbance on progress.

Under an individualistic form of society it is difficult to alter the social technique of change, and to make its credits really pay for the debits, and make all the people who gain by the profits on new capital pay also for the losses on prematurely displaced capital, or the gainers by cheapness and variety pay the human costs of unemployment and no-longer-wanted skill. The *basic* economic reason for social unemployment relief is not the humanitarian argument of social obligation against distress, *or* the argument against revolution, but the plain argument that the social gainers by innovation should bear the losses of innovation. At the same time much can be done to shorten the hitherto natural time span and make society ready to absorb the quickened *tempo* of science. No prices ought to be charged except on the basis of costs fully loaded with short-period obsolescence—this would prevent over-rapid substitution, economic only to a narrow range of people. We have no adequate technique of change : we treat life as mainly static, with occasional and exceptional periods of change, whereas we must learn to look upon it as continuously changing, with occasional and abnormal periods of rest, and we have to secure all the changes of social outlook implied by that reversal of view.

The next field in which scientific advance alters the economic problem faster than we can solve it, is in the duration of human life. We have to provide social dividend adequate to maintain a much larger proportion beyond the age to contribute to it. Combined with the altered birth-rate, a profound change is taking place in age densities, and the turnover from an increasing to a stationary and then a declining population, in sight in this country, Belgium, Germany and even the United States, is bound to affect the *tempo* of economic life. A larger and more immediate problem of adjustment is, of course, the absorption of the results of science not in increased masses of new kinds of commodities made by the released labour of labour-saving devices on old kinds, but in generalised leisure. The transition from a state of affairs in which we have an uneconomically high commodity wage paid to a part of the population, and the rest with a mere pittance and enforced idleness, to a state where a part of the reward is taken *all round* in larger leisure, and where economic satisfaction from leisure is deliberately equated to that from commodities in the standard of life, may need a surgical operation, or a catalyst, such as the United States experiment can show.

In the past, the absorption of innovation has been achieved, according to contemporary explanation, by four agencies :

(1) Great elasticity of demand for the old commodities at reduced prices—food and staple household necessities.
(2) Rapid introduction of new things.
(3) The rise in population *created* by the increase in produce.
(4) Overseas outlets in more backward industrial countries.

In the first the elasticity completely alters as the standard rises, and generally there is not now the scope for lower price in food or clothing increasing the demand *pro tanto* ; for the third, a rising standard no longer stimulates population but tends the opposite way ; for the fourth, the external outlets

are now largely self-producers. As regards the rapid introduction of new things—these mostly now demand increased leisure for their proper absorption and use, so that the two are co-related and mutually dependent.

It can be conceived that a socialistic organisation of society could obviate such of the maladjustments as depend upon gains and risks of absorption not being in the same hands, and a theoretic technique can be worked out for the most profitable rate of absorption of scientific invention having regard to invested capital, and skill and local interests. It is sufficient to say that it needs a *tour de force* of assumptions to make it function without hopelessly impairing that central feature of economic progress, viz. individual choice of the consumer in the direction of his demands, and an equally exalted view of the perfectibility of social organisation and political wisdom. But in the field of international relations and foreign trade, which alone can give full effect to scientific discovery, it demands qualities far beyond anything yet attainable.

Economic life must pay a heavy price, in this generation, for the ultimate gains of science, unless all classes become economically and socially minded, and there are large infusions of social direction and internationalism, carefully introduced. This does not mean government by scientific technique, technocracy, or any other *transferred* technique, appropriate as these may be to the physical task of production. For human wills in the aggregate are behind distribution and consumption, and they can never be regulated by the principles which are so potent in mathematics, chemistry, physics, or even biology.

SECOND EVENING DISCOURSE

MONDAY, SEPTEMBER 11, 1933.

THE WORK OF THE SAFETY IN MINES RESEARCH BOARD

BY

PROF. J. F. THORPE, C.B.E., F.R.S.

THE Safety in Mines Research Board is appointed by and reports to the Secretary for Mines and is financed liberally from the Miners' Welfare Fund. Its experimental work is carried out at two Research Stations, one at Harpur Hill, Buxton, and the other in Portobello Street, Sheffield, where it is in close association with the Department of Applied Science of the University. Both these Research Stations are under the direction of Dr. R. V. Wheeler, to whom Dr. H. F. Coward is Assistant Director. Falls of roof and haulage accidents are investigated by Major Hudspeth, Chief Mining Engineer to the Board. The Board works also through a number of sub-committees, of which the Explosives in Mines Research Committee, the Spontaneous Combustion Committee, and the District Support of Workings Committees may be regarded as types.

Time does not permit me this evening to deal with the great problems under investigation by Major Hudspeth and his staff, although it is evident that such problems are of great importance in relation to mine safety. Indeed, by far the greater number of casualties and fatal accidents in coal mines, during the period 1922–31, have been due to falls of ground and haulage accidents. Thus persons killed through explosions during this period numbered 521, whereas the deaths due to falls of ground and haulage accidents were 5,199 and 2,276 respectively. Nevertheless the casualties due to the two causes last named are mainly adventitious, and it is difficult to subject them to scientific, as distinct from human, control. On the other hand the causes of explosions and their elimination can be made the subject of scientific investigation and the fact that the terrible disasters of the past no longer occur must be ascribed to the application of the knowledge which has been gained by scientific research and investigation. It is my object this evening to describe the way in which this has been done and to show the many causes which may lead to the ignition of gas, and the methods which are being taken to remove these causes.

All the experiments have been arranged at the Board's Sheffield Research Stations by Dr. H. F. Coward. Three members of the staff, Messrs. Hartwell, White and Russell, are in attendance as demonstrators.

SAFETY IN COAL MINES.

The conditions of coal-mining create dangers from which other industries are free.

The fact that work may be carried on underground at depths up to a mile

below the surface of the earth, and perhaps two or three miles from the pit-bottom, causes the problems of roof-support and underground transport of men and materials to be particularly difficult. It is not surprising, therefore, to find that accidents due to falls of roof and accidents incurred during underground haulage are by far the most numerous.

Yet the accidents which cause most concern, both to the miner and to the public, are those due to explosions. Partly, perhaps, because of man's inherent dread of fire ; and partly because an explosion so often claims many victims.

Explosions may be caused either by gas or by coal dust. During the process of formation of coal from decaying vegetable matter, a process of bacterial fermentation, the gas methane, the fire-damp of coal mines, was evolved. This gas remains to-day pent within the coal substance, or stored in the associated strata, whence it may be liberated into the mine workings with disastrous results. Coal dust, if fine enough, forms explosive mixtures with air as dangerous as or, in some respects, more dangerous than mixtures of firedamp and air.

Efforts to eliminate explosions and, more importantly, the fear of explosions from coal-mining, have been fairly successful, more particularly as regards coal dust explosions. Little by little the various causes of explosions, of the initial ignition of firedamp or coal dust, have been recognised and controlled. Our aim is to eliminate them completely.

The greatest danger, initially, of explosion lies with firedamp, because its presence, unlike that of coal dust, may remain unsuspected ; and because it is so easily ignited. Firedamp is only explosive, however, when mixed in certain proportions with air, between the ' lower limit ' of about 5 per cent. and the ' upper limit ' of about 14 per cent. If, therefore, the gas, as it issues into the workings, is so diluted with air that it never forms more than 5 per cent. of the atmosphere anywhere in the mine, it ceases to be dangerous. Good ventilation of the mine is thus the primary safeguard against firedamp explosions, and there are, in consequence, stringent regulations governing the ventilation.

Supposing, though, that the ventilation fails to be effective, there are many potential means of ignition of firedamp in the pit. Each of these potential means of ignition—lights, explosives, electricity, frictional sparks—has to be safeguarded. Much of the experimental work on safety in coal mines, that is being carried out in this country and abroad, is directed towards safeguarding all possible means of ignition of firedamp.

Coal dust, which during one period in the history of coal-mining, constituted the more formidable danger, can be rendered harmless as an explosive agent. Credit, perhaps for the discovery and certainly for the practical application of the remedy, stone dust, is due to a Yorkshire mining engineer, the late Sir William Garforth.

The application of the remedy, the spreading of fine stone dust wherever coal dust can accumulate in the mine workings, so that the mixture is incapable of propagating flame when raised as a cloud in air, appears at first sight to be simple, but the problem is complicated by the fact that there is not a dead level of inflammability of coal dusts. Some coal dusts are much more inflammable than others, and require to be treated with a proportionately greater quantity of stone dust before they can be regarded as harmless. Wise mine managers treat the roadways of their mines with an excess of stone dust considerably above that required by regulations ; and it can be said with some confidence that, in this country, the widespread disasters due to coal dust extending small firedamp explosions throughout the

workings of the mine, such as occurred in 1905–12, need no longer be feared.

The study of the causes of mine accidents, whether they be due to falls of roof, to mishaps during haulage or to explosions, and the devising of remedies, are not in themselves sufficient to secure the increased safety of the mine worker that we all desire. Often enough, the application of a remedy against an accident rests with the miner. It is necessary, therefore, to instruct the miner, who has shown himself most willing to be instructed, as to the reasons for the measures for safety, sometimes arduous, that he is called upon to perform, and as to the risks he runs if he neglects them. For this reason the educational work of the Safety in Mines Research Board ranks equal in importance with its experimental work.

Experiments.

Experiment I.—Experiments on propagation of flame in methane-air mixtures.

Mixtures.—10 per cent. methane-air mixtures. Measurements of the required amounts of air and methane are made by means of rotameters; after passing through a mixing apparatus the mixture is passed into the explosion tube.

Tube.—Horizontal glass, 19·5 ft. long, 2 in. diameter.

Ignition.—By single break spark between electrodes (4 mm. gap).

Experiment (*a*). *Propagation from open to closed end of tube.*—Mixture ignited by spark at electrodes 6 cm. from the *open* end of tube.

Propagation showing uniform movement and subsequent vibratory phase.

Experiment (*b*). *Propagation from closed to open end of tube.*—Mixture ignited by spark electrodes 2·5 cm. from the *closed* end of tube.

Higher mean speed of propagation with vibrations.

Experiment II.—Experiments on the inflammability of coal dust and the effect of stone dust thereon.

Test I.—Violent inflammation of a typical coal dust.

Test II.—Suppression of inflammation by using an adequate proportion of stone dust.

Typical coal-dust	45 per cent.
Fuller's earth	55 ,, ,,

Test III.—Partial suppression of inflammation by using less than the statutory amount of stone dust.

Typical coal dust	65 per cent.
Fuller's earth	35 ,, ,,

Experiment III.—Experiments on the ignition of methane in air by a heated surface and the effect of iodine on the ignition temperature.

Note.—The late Professor H. B. Dixon showed that traces of iodine had an inhibiting effect on the ignitions of methane air mixtures.

A jet of methane is passed on to a heated alundum surface, maintained at a temperature sufficient to ignite the methane in the surrounding air stream. When the air stream is passed over crystals of iodine at laboratory temperature (and thus contains 0·03 to 0·04 per cent. of iodine vapour) ignition does not occur owing to the inhibiting action of the iodine. It is proposed to erect two similar heated surfaces, cylindrical in shape. One will be maintained at a temperature just sufficient to ignite the jet of methane in air. The second apparatus will be used for experiments with air containing iodine to show that a higher temperature is necessary for ignition under these conditions.

Experiment IV.—Experiment showing the ignition of firedamp by heat of impact of handpick on rock.

The apparatus consists of a wooden box 2 ft. by $1\frac{1}{4}$ ft. by 1 ft., fitted with oiled paper releases and a glass observation window. Attached to the pick is a rubber diaphragm, covering a circular hole in the cover of the chamber. The stretching of the rubber is sufficient to allow of a good blow of the pick.

Sufficient pure methane is admitted to the chamber to give an approximate 7 per cent. methane-air mixture. A sampler, fitted with platinum electrodes, is attached to one side of the chamber to check this percentage.

The rock used is that suspected of causing ignition at Canavan's Mine, Valleyfield Colliery. A glancing blow of the pick on the rock must be delivered to cause ignition, there being a bright yellow flash at the point of contact.

Experiment V.—Experiments on signalling with bare wires.

Pit conditions render it necessary that signalling should be possible at any point in the roadways over a distance of perhaps four miles, and it is, therefore, only possible to do this by means of bare wires which are crossed to make the signal.

The bare wire connections from a signalling bell are brought into contact in a mixture containing 8·3 per cent. of methane, confined in a glass vessel of approximately 400 cc. capacity. A vertical exit tube, closed by a loosely fitting rubber bung, provides a release on ignition.

Bell.—A.T.M. (Automatic Telephone Manufacturing Co.) Model, working on 24 volts.

Experiment (*a*). *Unsafe condition.*—A 500 ohm shunt, connected in parallel across the ends of the magnet windings, is disconnected by means of a switch. Signalling by bringing wires in contact causes ignition.

Experiment (*b*). *Safe conditions.*—The 500 ohm shunt is connected across the coils. No ignition occurs on signalling.

Experiment VI.—Experiment with clay and sand-clay stemmings.

Blown-out shots are a possible cause of ignition and lead to loss of efficiency in the use of the explosives. It is found that sand-clay remains but clay is ejected as stemming—a mixture of sand and clay is actually used.

Experiment.—Lead tubes, 2 ft. long and 2 in. bore by $\frac{1}{8}$ in. wall are used. A wooden piston with a brass handle has been made to fit these tubes closely. When clay is packed into one of these tubes, little force is required to push the material through the tube. With sand, hammering of the piston produces a bulge of the lead wall and the sand is not ejected.

Experiment VII.—Lamp testing experiments.

A flame lamp (No. 2A Davis-Haydock pattern) is raised into mixtures containing from 1 to approximately 6·5 per cent. of methane in the Oldham chamber. The mixtures are prepared by means of rotameters.

As the percentage of methane in the air is raised from 1 per cent., the flame of the lamp becomes gradually higher and is finally extinguished in a mixture containing approximately 6 per cent. of methane. This latter mixture is ignited with a taper.

Experiment VIII.—Showing that a lighted cigarette does not ignite a 6 per cent. methane-air mixture.

Experiment IX.—Illustration of spontaneous ignition by means of pyrophoric iron.

Models.—Sheathed explosives.

Films—

Film (1).—Showing a demonstration of a coal dust explosion at the Research Station, Buxton.

Film (2).—Showing shot firing with

(*a*) Clay stemming.

(*b*) Clay and sand stemming.

Slides—

(*a*) Showing total casualties in coal mines.

(*b*) Showing total fatal casualties.

(*c*) Showing effect of stone dusting on casualties due to explosions.

CONFERENCE OF DELEGATES OF CORRESPONDING SOCIETIES

THE Conference was held in the Lord Mayor's Rooms, Hastings Street, Leicester, on September 7 and 12, under the presidency of Dr. R. E. Mortimer Wheeler, F.S.A., 43 delegates attending representing 52 societies, in addition to a large audience.

Thursday, September 7.

The President conveyed the congratulations of the delegates to the Manchester Statistical Society upon the recent attainment of its centenary. Mr. Frank H. Roby, representing the Society, responded.

The delegates considered the following report communicated by the Secretary, which was approved and adopted.

> 'Committee to take cognisance of proposals relating to National Parks by the Government and other authorities and bodies concerned, and to advise the Council as to action if desirable.'

The Chairman and Secretary report that no proposals have arisen during the past year requiring the consideration of the Committee ; and in view of the improbability of any such proposals arising in the immediate future under the prevailing financial stringency it is recommended that the matter might suitably be referred to the Corresponding Societies' Committee, with power to co-opt thereto competent members for the special consideration of the subject should occasion arise.

ADDRESS ON

THE CENTRALISATION AND CO-ORDINATION OF RESEARCH IN ITS RELATION TO LEARNED SOCIETIES

BY DR. R. E. M. WHEELER,
President of the Conference.

WE live in a period of feverish co-operation. We co-operate to wage war, to inflict peace, to abolish old frontiers and to create an infinitude of new ones. But whatever the difficulties of political or economic co-operation, an effective co-ordination of effort on an international scale within the limits of any scientific discipline should be practicable without a disproportionate expenditure of effort. That difficulties of one kind or another will indeed arise even in so impersonal a pursuit as that of knowledge is, of course, inevitable so long as man remains a political animal. For instance, quite recently, in a branch of science which shall

be nameless, steps were taken for the first time since the war to organise an international conference. All went well until the question of *locale* arose; and in the controversy which ensued, the detached observer could not but recall to himself Mr. H. G. Wells's remark that 'Europe is sunk in pits of stale and unventilated history.' As a matter of interest, I may add that, out of the whole of Europe, only in two regions would the delegates of the various nations consent without exception to meet in conference—namely, in Scandinavia or in Great Britain. The choice of Scandinavia, which has, I suppose, always been the least provocative part of Europe, calls for no comment. But it cannot by the most ardent patriot be averred that Great Britain has always maintained a similar detachment, and we may perhaps flatter ourselves that the final choice of this country for the international conference in question was due to something more than a purely negative quality in our national character.

This mention of national character brings me to a point which will probably be implicit in much that will be said to-day. My main subject is the problem of co-ordination of effort amongst the various scientific societies of Great Britain; and our discussion will be more than tinged with unreality unless we realise quite clearly at the outset that neither co-ordination nor effort is, in the senses which we have in mind, an outstanding quality of the British character. We make a fetish of individual freedom to the extent of inhibiting ourselves with all sorts of restrictions to prevent that freedom from being violated; and so inclined are we to laziness that we impose upon ourselves all manner of strenuous enjoyments as an alternative to work. To these queer complexes we shall have perpetually to refer any scheme of formal co-operation to which logical argument may lead us. We may all agree in the abstract that duplication of research is a waste of time and money, and that some efficient mechanism whereby results may be freely interchanged and policies co-ordinated would materially hasten the advance of knowledge. It is, however, one thing to draw up a logical scheme of the kind and quite another thing to put it effectively into operation. The personal qualities to which I have alluded do not induce us in this country, even as scientists, to conform easily to the dictates of logic and method, that blessed word to which our Teutonic friends are so devoted. One may perhaps go so far as to say that any Englishman is perfectly prepared to make a principle of his practice, but will see you further before he makes a practice of anyone's principle. In other words, any effective attempt at further co-ordination amongst the various bodies which we represent here to-day will proceed rather by the amplification of present effort than by any attempt to impose a brand new complete and highly-principled scheme.

By way of introduction, therefore, to the discussion which is our main function this afternoon, it may be useful to review briefly some of the efforts which have been or are now being made to collate and to prevent waste of effort amongst scientific bodies. I shall take my examples mainly from the province with which I myself happen to have an immediate contact—that of archæology, though, at the same time, I am fully conscious that, in certain respects, other branches of research have already reached a more advanced stage alike of centralisation and of judicious delegation.

In his Presidential address to the Society of Antiquaries a few years ago, Sir Charles Peers dealt in some detail with the desirability of reviewing the whole field of scientific archæology in this country at the present time and of drawing up a considered policy of research. Subsequently, Sir Charles opened a discussion on the same subject at the Annual Congress of Archæological Societies at Burlington House. He pointed out, on the

one hand, the unprecedented extent of the work, particularly field-work, now being carried out in Great Britain both by central and by local archæological societies ; and he appealed, on the other hand, for a greater co-ordination of this work and for a more fitly proportioned distribution of energy over the whole field of study. Incidentally, he pointed out certain specific directions in which current research was overcrowded and others in which progress had been unduly retarded.

Before we consider the ways and means whereby a reasonable policy of the kind can be implemented, let us glance at some of the causes of the present inequality of effort in the province with which I am, for the moment, concerned. It will, I think, be found that parallel causes are in greater or less degree the basis of similar difficulties in other branches of science.

In archæology, we are at the present time approaching the end of a transitional phase. A generation or two ago, the science—then only partially scientific in method—was still essentially an amateur accomplishment. As such, it was widely cultivated by the country gentry, who formed the nucleus of most of our learned societies. Some of the research carried out under these conditions was surprisingly good ; much of it, less surprisingly, bad. But whatever the value of this work in detail, it had—and, so far as it continues, still has—one outstanding and overwhelming merit. If it did not necessarily create a scientific understanding of archæology, it at least established and maintained a widespread sympathy for that study, and so, more than any other factor, prepared the way for the next great advance.

That advance is best symbolised by the inauguration of centralised State effort. The first symptom of the new order, in this country, was the passing in 1882 of the first Ancient Monuments Act, giving the government slight and nebulous powers for the preservation of certain classes of antiquities. I describe this primitive Act as nebulous. It was, indeed, a cloud no bigger than a man's hand. It had behind it, however, though not in this country, a significance out of all relation to its initial size. As long ago as the second half of the eighteenth century, the great Gustavus III of Sweden had instituted a State inquiry into the antiquities of that country. We need not inquire too closely into his motives, which were perhaps as mixed as those which have induced another autocratic statesman of more recent days to expose and to advertise the grandeur of Rome. But the Swedish example has been taken up during the past century in France, Germany, Spain and, recently, in Ireland, to an extent that enables us to regard a considerable measure of State control in matters archæological as a normal function of a civilised country at the present time.

In Great Britain, the protoplasmic Ancient Monuments Act of 1882 has grown successively into the Acts of 1913 and 1931, and has incidentally brought into being the three Royal Commissions which are now busily engaged upon recording the ancient and historic structures of England, Scotland and Wales. The growth of the Ancient Monuments Department of H.M. Office of Works, which administers the Act, and of the three Royal Commissions is a factor of primary importance in our problem in so far as it is concerned with this particular study.

Its importance is this. With the parallel but more reluctant growth of museum organisation, it has created a nucleus of what may best be called professional archæology. It might be argued that the emergence of archæology as a science and its emergence as a profession are really one and the same thing. One may, indeed, claim archæology as the youngest of the sciences, and, if only for that reason, you will, I trust, forgive me for devoting an unconscionable share of my remarks to it.

Now this new professional status of archæology has had, and is having, a number of rather important reactions. In the first place, the universities are devoting an increasing amount of attention to it—at least seven new chairs and lectureships have been created since the war—and so are just beginning for the first time to impose a sort of academic monopoly upon the science. In the second place, the position of the older type of local society is undergoing a change by reason of the widening gulf between the amateur and the professional. In the third place, so long as the profession remains a relatively small one, it is on its part peculiarly liable to develop within itself an excessive narrowness and isolation—in fact, the vices of most restricted professionalism.

All these are in one way or another disruptive influences. They are tending to divorce the archæologist from the layman whose sympathy and help are perhaps more necessary in this branch of knowledge than in any other. They are tending to divide professed archæologists themselves into schools which reproduce their own kind, and—of all vices the most subtly noxious—the new science is inclined to suffer from a kind of snobbism which the older sciences have largely outgrown. With the minutiæ of these dangers and diseases I am not here concerned. Something may be said, however, on broad lines of the attempts which are being made, or might profitably be made, to remedy them.

First, let us take the broadening rift between the professional and the layman. Here, interest and duty agree in fixing the responsibility. The professional scientist, and he alone, can properly stimulate that great mass of lay opinion upon which not a little of his own achievement must ultimately depend, whether in the form of individual or of corporate patronage. On all grounds, a close liaison between professional science and the lay public is essential to the maintenance and development of research.

This may sound a mere truism, but it is a truth of which three-quarters of professional science is unappreciative. And in re-affirming it to-day, I would urge it not merely from the motives of professional self-interest to which I have referred. I would urge it also as a salutary counter-irritant to one of the worst afflictions from which a closely-restricted professionalism can suffer. A few years ago in a presidential address at a meeting of the British Association, attention was drawn to the plague of pedantic verbiage which had infested modern science, and a plea was made for simplification and classification. That plea was a timely one ; it might fittingly have been extended from professional science to such activities as professional football, professional cinematography and professional journalism. The dangers of scientific jargon are twofold ; it adds to the obscurity of science from the lay standpoint, and, sooner or later, it tends to obscure and obstruct scientific thought itself. I have just been turning over the pages of an excellent journal which makes it its business to present the results of scientific archæology to the general public, and my eye has caught three articles by three of the most distinguished archæologists of the day. On one page I am caught up in the astonishing hyphenated word ' leaf-shaped-sword-culture-complex ' ; on another, I see the dark phrase ' the diagnostic value of negative lynchets ' ; on a third, the remarkable sentence, ' These names were left by the equestrian inhumators who brought in the later Hallstatt culture.' One may perhaps suppose that the ' equestrian inhumators ' had their counterpart in such folk as ' pedestrian incinerators,' and were the forbears of such distinguished sects as the ' aerial seventh-day Adventists ' and the ' submarine Rosicrucians.' In any case we may best describe this obscurantist jargon by the one simple word, Hokum. And, whatever may be the case in other branches of science, it is sufficiently

certain that in professional archæology at the present day, Hokum is on the increase. Learned and estimable young men in baggy trousers and suède shoes are spreading contagiously from our universities and are beginning to cloud their science and their own minds with a whole lot of unnecessary Hokum, fortifying themselves the while with the disastrous slogan, *Odi profanum vulgus et arceo.*

The remedy, could it be enforced, is an easy one. Could these young men—and, indeed, some of their elders—but be compelled to explain their ideas periodically to, shall we say, the Netherwallop Antiquarian Society and Field Club in language intelligible to the local birdscarer, then could we begin to hope at length for clarity of expression and clarity of thought. But what in fact happens in all too many cases is this. A young man of ability goes up to one or other of the older universities and there comes under the influence of a highly-specialised teacher, who instils his own special tastes and ideas into his disciple and ultimately secures a fellowship for him. The youth remains at the university for the rest of his mortal existence, coming only intermittently and accidentally into contact with the *profanum vulgus* beyond its walls. I am speaking now in particular of my own science of archæology, where the number of professional openings outside the universities is restricted to an extent perhaps unparalleled in any other branch of science.

In this problem, therefore, of the co-ordination of research, I would begin by urging a closer contact and sympathy between the scientist and the general public. That contact is the return which, whether in its individual or its collective capacities, the general public has the right to demand for its constant and, on the whole, liberal support of research. Furthermore, the maintenance of contact is in itself a fine discipline for the scientist, compelling, as it does, a constant simplification and valuation of ideas. In other words, it is an excellent and essential antidote to that insidious professional pedantry which I have here called Hokum.

I have spoken so far of the inter-relationship of layman and professional as it were of the interchange of courtesies between aliens, and I have not hesitated to put this vital factor into the forefront of my remarks. I now turn briefly to the more domestic problems of effective co-operation within the actual limits of organised science. In particular, we are faced at once with that ever-recurring problem of the proper working-relationship between the more central scientific bodies and the more local organisations. In this connection, I cannot refrain from expressing a personal regret that the central scientific societies in London and Edinburgh do not take a more active interest in assemblies such as that which I now have the honour to address. This aloofness is detrimental to the interests alike of the central societies and of their provincial kindred, and is in some sense another aspect of that snobbism to which I have already referred as a disruptive force. I speak with the impartiality of one who is a member both of more central and of more provincial societies than my banker cares to contemplate ; and it seems to me that, in future years, something might perhaps be done to secure a participation of the great metropolitan societies in our proceedings. It would be impertinent for me to point out here the fundamental value of the output of many even of the most local of provincial societies. But I would remind you that we have already had occasion to-day to congratulate the Manchester Statistical Society on the completion of a century of useful industry, and would emphasise also the solid scientific work, produced over a long period of years, in zoology, botany, geology and archæology, by closely-localised organisations such as—to take a random example—the Cardiff Naturalists' Society. I recall as significant the delighted surprise with

which the Transactions of the Cardiff Society (now covering a period of over half a century) were discovered for the first time two or three years ago by one of the great scientific societies in London. There is abundant evidence, indeed, that the gulf between the central and provincial societies is still an unnecessarily wide one. How can it best be narrowed ?

Here we are up against certain of those traits in the British character to which I referred at the beginning of my address. It would be easy for a central society to draw up a clear-cut programme of research and to allocate to local bodies appropriate shares in its execution—shares, that is to say, appropriate to the environment and attainment of these various local organisations. Could this ideal scheme be carried out with reasonable precision over a period of years, there is no doubt that, in theory, the ratio of achievement would increase with leaps and bounds. Such, however, is the unreasonable nature of our British temperament that any attempt to conscript science in this sort of way is liable to immediate disaster. We are all anxious to learn but hate to be taught, and any semblance of dictation is calculated to arouse all the most unthinking obstinacy in our nature. Nevertheless, the difficulty is one of method rather than of principle, and I would again refer to the carefully-considered statement of the present position of archæological research recently promulgated by the President of the Society of Antiquaries. On this a further word may be said.

This statement, drawing attention to the major desiderata in British archæological research at the present time, owes its importance to two factors. In the first place, under the leadership of Sir Charles Peers, it received a very thorough preliminary consideration from a committee representing all the principal interests and localities throughout the country. In the second place—and I would draw special attention to this factor—it was discussed by and disseminated through a thoroughly representative Congress of provincial societies. These societies had thus a direct voice in the final formulation of the statement, and ultimately received it in a shape which all or the great majority of their representatives regarded as acceptable and workable. How far the positive recommendations of the scheme will be carried into effect by these societies, it is at present too early to say, but, without going into details in the present context, I may observe that certain preliminary steps have already been taken in the right direction.

Here, then, we have a scheme of co-ordination, drafted first by a central society and then shaped and approved by the provincial societies in conclave. The whole procedure was, we may say, parliamentary and British, and is, I think, a fair sample of the kind of method which, at any rate in certain branches of science, is likely to yield the most satisfactory results. The essential medium was, as I have indicated, the congress of appropriate societies; and although the principle of procedure by conference is perhaps sometimes overdone, it seems to be that method which most nearly accords with the needs of the age in which we live. I have in mind not merely the Congress of Archæological Societies but other co-ordinating bodies such as the South-Eastern Union of Scientific Societies, which, incidentally, owes so much to the enterprise of our Secretary, Dr. Tierney. Here, in the South-Eastern Union, we have an organisation through which, in particular, the smaller local societies find a useful and stimulating medium of exchange. I would emphasise the word ‘ useful ’ and would give one example to illustrate my point.

The illustration is indeed one of several which will occur readily to the minds of many of you. You will recall that, as the Great War proceeded, our Local Government Board realised the potential source of dangerous

infection to the population of this country through the introduction of the malarial parasite by infected troops returning in large numbers from Macedonia, Gallipoli, Mesopotamia and elsewhere. The Board accordingly instituted inquiries amongst local scientific societies to ascertain the prevalence and distribution of anopheline mosquitoes in England and Wales. In the course of this investigation, the suspicion arose that an elusive tree-hole breeding species of anopheline mosquito (*Anopheles plumbeus*) was capable of becoming an infected intermediary host of the malarial parasite, and of transmitting it. This suspicion was confirmed, and special steps were promptly taken to ascertain the distribution of the noxious species. The task was not an easy one, and its accomplishment was due in no small degree to the officially-invited co-operation of the South-Eastern Union of Scientific Societies, by which inquiries were instituted among the affiliated societies throughout the Union's area.[1] As the result of these and parallel researches, the danger was successfully countered ; and the ravages of malaria, which have been ingeniously credited with the decline and fall of the ancient Greek and Roman civilisations, cannot now be saddled with the responsibility of any declension in our own.

The example which I have just given emphasises the utility of regional congresses or unions of scientific bodies as a machinery for stimulating and co-ordinating effort. At the present moment, I believe, steps are being taken to form some such union for the great midland area in which we are meeting this week. The movement deserves all success, and should be followed in other parts of the country. The more numerous local scientific societies become—and they have increased rather than diminished in numbers since the war—the more urgent becomes the need for systematic co-ordination. A general meeting held once a year under the auspices of the British Association is no sort of substitute for regional organisation. Let me refer in this context to the co-operative movement which has, during the past decade, been growing in strength amongst the museums of England and Wales. The wasteful rivalries and petty jealousies which had tended to obstruct the proper functioning of local and, indeed, of national museums seemed to some of us *not* to be the inevitable alternative to apathy and ineffectiveness ; and schemes whereby smaller museums could work in affiliation with larger museums on a regional basis were brought into operation. The method was first evolved, I think, in Wales, which happens to be an obvious and convincing territorial unit and where, incidentally, co-ordination in a country so sharply subdivided by geography and tradition was specially desirable. The result of the experiment there has been completely successful ; the local museums and the National Museum to which they are affiliated have alike benefited in various important directions which I need not here particularise. The Welsh example has been followed in Lancashire and Cheshire and elsewhere, and the movement as a whole received strong approval and encouragement from the recent Royal Commission on National Museums and Galleries. No central national organisation—however useful as an ultimate co-ordinating authority—can replace regional organisation of this kind, whether amongst museums or amongst other scientific institutions, as a practical solution of the problem with which I am here concerned.

Lastly, as a mere spectator in the fields of natural science, I freely confess to a feeling of envy for the comparative simplicity of the problem of co-operation in those researches which do not directly relate to the handiwork of man. The distribution of a species, the ecology of a plant, can be

[1] The history of the investigation is summarised by Dr. Tierney in the *Transactions of the South-Eastern Union of Scientific Societies*, 1923.

studied up to a point through the instrumentality of relatively unskilled labour. A specimen can be sent up for verification ; it is rarely unique in the locality where it is found, and its *locale* can therefore be verified, if any particular report or record is open to doubt. But in the scientific study of man—in archæology, anthropology, tertiary or quaternary geology—this is, as a rule, not the case. The value of a bone or an artifact is generally the value of its finder's skill and acumen. Its intrinsic interest is very often negligible. Its precise relationship, before disturbance, to the strata in which it lay is probably of cardinal importance. But that relationship is intelligible only to the highly trained eye, and, once disturbed, can rarely be reconstructed or satisfactorily checked. Under such circumstances, what I have called ' unskilled labour ' is nearly useless, and semi-skilled labour, through misinterpreting the subtleties of a discovery, may be a positive danger. It is, I suppose, the destiny of the human sciences—the sciences relating directly to man—to be inexact. I turn therefore more hopefully to those sciences which are of a more reputable kind, which deal, it may be, with the inferior orders of creation but can at least deal with them in a very superior way. And I conclude by inviting what I may call a ' descriptive discussion ' of the efforts and needs of the various branches of organised science for more effective organisation.

Dr. G. C. Robson.—*Zoological Surveys.*

Dr. Robson, inviting the co-operation of societies in the compilation of zoological surveys in their own areas, drew attention to the value of such surveys, especially where the results are published in the transactions of some central organised body embracing the area, such as a union of scientific societies, where such records as may prove of value are more readily accessible for scientific reference than when published in the proceedings of societies having a purely local circulation amongst their own members.

In the discussion which followed, Captain T. Dannreuther reported upon the development and progress of the Insect Immigration Survey undertaken by the South-Eastern Union of Scientific Societies. Mr. R. Adkin, Prof. F. Balfour Browne, Dr. F. A. Bather, F.R.S., Mr. T. Sheppard, Dr. G. F. H. Smith, and Mr. E. W. Wignall also contributed.

Tuesday, September 12.

Mr. T. Sheppard, M.Sc., Chairman of the River Hull Pollution Committee.—*The Effects of Pollution on the Flora and Fauna of Rivers. The Pollution of the River Hull.*

(Ordered by the General Committee to be printed in full.)

I have been asked to address the Conference of Delegates from the Corresponding Societies of the British Association on the subject of the cause and effect of the pollution of the river Hull, for two reasons : (1) that the work was largely carried out by amateurs, members of local scientific societies ; and (2) that our experience of what to do, and more particularly, what not to do, may be of service to members of the Corresponding Societies in whose areas similar investigation might profitably be carried out.

The river Hull has its source at Emswell, near Driffield, in East York-

shire, and its upper reaches, where it emerges from the chalk, form one of our best trout streams. It flows in a southerly direction along the west of the ' Isle of Holderness ' until it reaches the estuary of the Humber at the city usually called Hull, though its correct name is Kingston-upon-Hull. In its lower reaches the river is tidal and very brackish. When it is remembered that the Humber is fed by the Trent and Ouse, and their tributaries, which carry the sewage from a large proportion of the towns of the north of England, in addition to which a fair share of the material denuded from thirty miles of the Holderness Drift cliffs is carried into the estuary, it will be understood that this area is not of much interest to anglers.

The area reviewed in these notes therefore is a matter of sixteen miles between the Top Lock at Beverley, where the tidal influence ceases, and Driffield, about which place the trout streams are pure and well stocked with fish.

The growing population at Driffield and Beverley, with the increase in factories; sewage disposal works; the more modern methods of agricultural drainage, with its contamination caused by the increase of artificial and other manures on the land, as well as the effect of tar sprays and petrol washed from the roads, all have helped to change the nature of the fauna and flora of the river.

Many years ago Hull's water supply was extracted from the river Hull, and was passed through filter beds at Stoneferry to the north of the city. A serious epidemic at Beverley was followed by a much more serious outbreak at Hull, for, while the filter beds clarified the water, they were unable to extract the bacteria. Since then Hull has bored into the chalk for its water supply.

In that section of the river which has had our supervision for some years, the anglers first drew attention to the fact that sections of the stream, which once were prolific, are now almost useless for angling purposes. While making investigations in a part of the river Hull known as Whinhill, we record that a man ' who gave his age as 76 years, stated that the most interesting day of the week on which to view the canal at Whinhill is Tuesday, as on that day " blood and suds " come down the stream ; blood from the slaughterhouses at Driffield, Tuesday being killing day ; and " suds " from the washing of clothes which takes place on the same day of the week.' He also stated that years ago the stream was full of fish, and now there is not one.

The members of the various angling societies in the district, realising that the changes in the river were resulting in the fish gradually disappearing, appealed to the Yorkshire Fishery Board, which in turn appealed to the Ministry of Agriculture and Fisheries. That Board sent its scientific representative, Dr. E. C. Jee, to make inquiry, and eventually a local committee was formed, thoroughly to investigate the fauna and flora, the effect of sewage contamination, and the chemical and biological changes which were taking place.

This committee consisted of representatives of the Hull and Driffield angling societies, amateurs interested in the vertebrate fauna, mollusca, and other lower forms of animal life ; the flora and lower forms of vegetable life ; and chemistry, meteorology, etc., likely to affect the problem. These were drawn from the Hull Scientific and Field Naturalists' Club, the University College of Hull, etc., and the Hull Waterworks Department ; the Secretary was Commander A. L. Woods of the Ministry of Agriculture and Fisheries in Hull, the Chairman being T. Sheppard.

To begin with, periodic examination was made of the state of the microscopic fauna and flora of the river, as upon these the freshwater snails, worms, etc., are fed, which in turn supplied food for the fish. In this way,

for some years, samples have periodically been taken at various points in the stream. The effects of sewage, gas-works effluents, and other sources of contamination were apparent, and having obtained sufficient scientific evidence to show that these sources of pollution had a detrimental effect upon the health of the river fauna, and were therefore likely to be detrimental to the health of human beings, interviews were arranged with the various parties concerned.

The nature of the filthy and evil-smelling slime which stifled the vegetation and made animal life impossible in the vicinity of sewage outfalls, told an obvious story. As a result, improvements have been made in the method of treating the sewage, and in preventing poisonous gas liquor from finding its way into the river, all of which is to the good.

The reports of the various observers of the macroscopic and microscopic fauna and flora, as well as the marvellous series of observations on the chemical and other properties of the water carried out month by month by Mr. N. C. Akers, have indicated certain directions in which experiments might definitely be made to ascertain the effect of the polluted water upon the fish in different parts of the river. For this purpose, with the aid of the Yorkshire Fishery Board and the local angling societies, large numbers of different species of fish were secured, and placed in specially designed cages at selected points of the river, and periodically examined. So far, however, the experiments have been largely of negative value, though we have been able to ascertain what to avoid in dealing with captive fish.

In the first place, most freshwater fish suffer by being handled, and still more during transport—so much so that the damaged scales, etc., readily lend themselves to the growth of a fungus which quickly causes a large mortality. Similarly, if the cages, though kept under water and with facilities for the fresh water to pass through, are too small, or unsuitable in their construction, and the fish damage themselves and thus soon die. Further, also, marking the fish in different ways before allowing them their freedom in the stream has given negative results, as none of the hundreds of marked fish has been recovered. At the present time trout, and 'goldfish'—which seem to be immune from many of the troubles referred to—are being subject to experiment. In any case the work has proved to be exceedingly interesting from a scientific point of view, and before our labours are completed we hope that results of a practical nature will accrue.

At the same time, however, as years go on, increasing population on the banks of the river and on its tributary streams, together with the necessity for disposing of the waste liquors from the factories which increase in size and numbers, all militate against a return to the 'good old times.' But the Ministry of Agriculture and Fisheries considers that the work done in East Yorkshire by amateur zoologists, botanists, chemists, and others might easily be undertaken in other areas; and the object of these notes is to suggest to the delegates that they consider whether they can help; and I am assured that the Ministry will give every facility and place its accumulated records at the disposal of any society inclined to take up this fascinating work.

As one who has missed but very few of the scores of meetings which have been held dealing with nearly all aspects of the question, I can assure you that the investigations are full of interest.

There are other aspects of the matter which I have not dealt with, but which are bound to arise, namely, the legal questions, which are keenly watched and contested by the legal representatives of the different parties. These difficulties and the wonderful arguments which have been brought forward are, I fear, beyond me; though they have been quite entertaining! This particular subject was dealt with by Mr. H. F. Atter in Section G yesterday.

Mr. J. W. Walton (Folkestone) contributed a note on the apparent deleterious effect upon the fish in the Royal Military Canal at Hythe, Kent, by the reduction of the water level and the dredging and cutting of plant growth in the canal. A discussion followed in which Mr. F. T. K. Pentelow, representing the Ministry of Agriculture and Fisheries, warmly welcomed the observation of local societies upon the variation and changes of the fauna and flora of the rivers within their respective areas. Mr. J. Adams, Mr. T. S. Dymond, Mr. H. E. Salmon, and Dr. J. F. Tocher also took part.

Mr. J. Fairgrieve read a paper on *The Amateur Meteorologist*, in which he directed attention to the importance and value of the meteorological organisation of this country, which was in large measure due to, and founded upon, the work of the amateur observer. He indicated ways and means whereby an extension of those observations and records would be of value, especially by observers in remote districts. Dr. G. C. Simpson, C.B., F.R.S., supporting Mr. Fairgrieve, stressed the desirability of societies undertaking regular local observation in their own areas and supplying such records to their municipal authorities, thereby affording material assistance in the compilation of the meteorological records of their own localities. Prof. F. G. Baily, Captain T. Dannreuther, the Rev. Pryce Jones, and Mr. T. Sheppard also contributed to the discussion.

ON PLANT GROWTH HORMONES (AUXIN *A* AND AUXIN *B*)

BY

PROF. DR. FRITZ KÖGL, UTRECHT.

(*Ordered by the General Committee to be printed in extenso.*)

THE experiments which I am about to bring before you were mainly carried out in conjunction with Dr. Haagen-Smit and Dr. Hanni Erxleben; they are based on modern researches on the physiology of vegetable growth—researches which we owe chiefly to the school of Prof. Went of Utrecht. As a preliminary I would summarise the chief results of these researches as follows: Whilst animal growth takes place almost exclusively by multiplication of cells, we must distinguish in plants between *cell division* and *cell extension*. The obvious increase in volume which is seen in higher plants depends principally on cell *extension*. Fig. 1 shows two stages in the

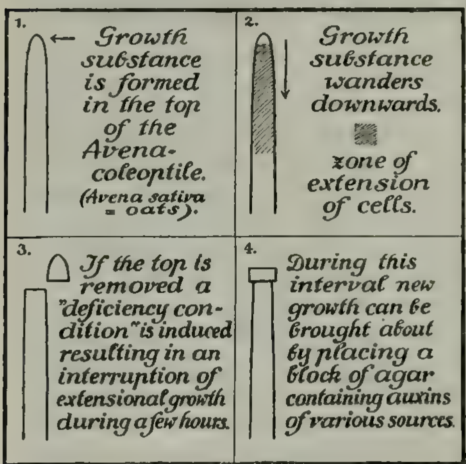


FIG. 2.

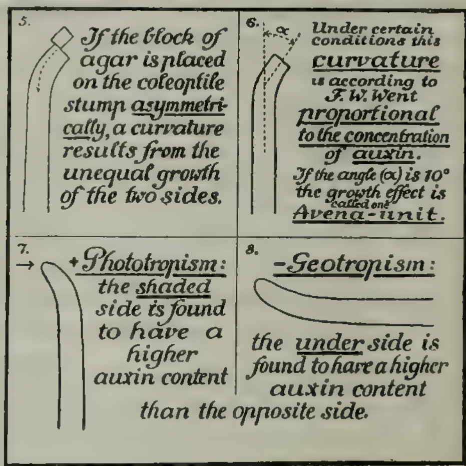
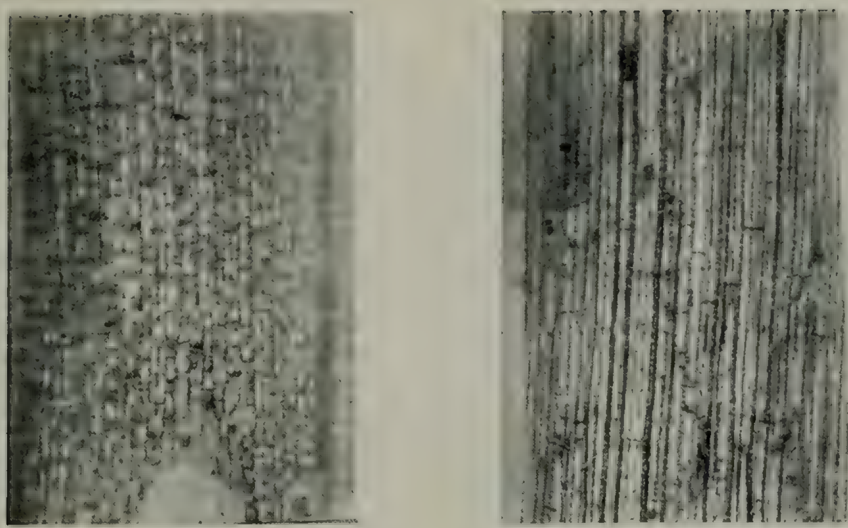


FIG. 3.

cell extension of oats seedlings. This extension takes place under the influence of definite growth substances, which may be termed *auxins*. The mode of their physiological action and recognition is represented diagrammatically in Figs. 2 and 3. The active substances are formed in the top of the seedling and wander from there into the base; if the top is removed a 'deficiency condition' is induced, resulting in an interruption of extensional growth during a few hours. During this interval new growth can be brought about by auxins from various sources. If the block of agar containing growth substance is placed on the coleoptile stump *asymmetrically*, a curvature results from the unequal growth of the two sides. Under certain conditions this curvature is, according to F. W. Went, proportional to the concentration of the growth substance; if the angle of curvature is 10° the



A B

Fig. 1.—Two stages in the cell extension of oats seedlings.
A = 2 days old; B = 4 days old.

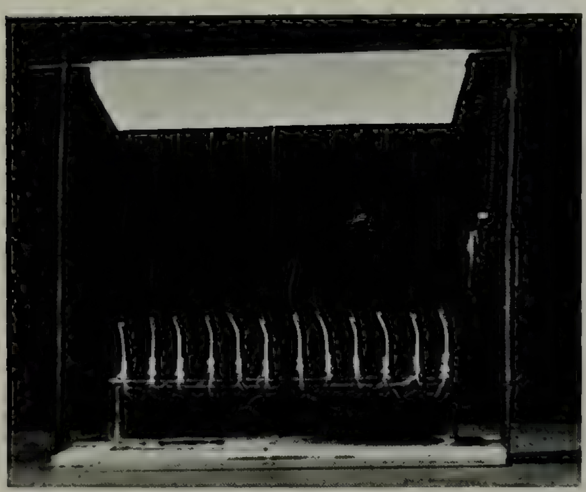


Fig. 14

Illustrating Prof. Kögl's paper on Plant Growth Hormones

[*To face p. 600*

growth effect is called one Avena[1] unit (A.U.). We may further mention that phototropic and geotropic curvatures are also caused by auxins; thus the shaded side of the shoot (in the former case) or the under side (in the latter case) are found to have a higher auxin content than the opposite side. The growth test of Went, by the help of which we were able to isolate the auxins, is best shown in a film. (Demonstration.)

When some two and a half years ago we were searching for a suitable source from which to isolate auxins, our attention was directed to the high auxin content of human urine. We know now that the isolation of the auxin from urine implies a concentration of 21,000 times; its isolation from the vegetable sources which were known at this time would have meant a concentration of at least 500,000 times. Under these circumstances it will be readily understood that we followed the line of least resistance and first attempted the isolation from urine, although this is an animal source, a circumstance which many botanists no doubt felt to be an æsthetic defect in our work.

We have earlier described the isolation of auxin from urine. The quantity of crystallised auxins which we have obtained so far from urine—about 400 mg.—would have just been sufficient for three or four combustions before Pregl introduced micro-analysis seventeen years ago. If, now, we had devoted all our energy to the preparation of pure auxin, it might have been possible to convert the trail or the footpath which led us to the crystalline substance into a high road. For the problem as a whole it seemed to us, however, more important to devote a part of our time to the study of new physiological problems which presented themselves; this also helped the chemical investigation in many ways; we were, moreover, able to compensate to some extent for the shortage of material by improvements in the preparative micro technique.

Micro-analyses, determinations of the molecular weight, and titrations, led us to the formula $C_{18}H_{32}O_5$ for auxin; this composition also agrees with that of the derivatives obtained so far. In addition to a carboxyl group the molecule contains three alcoholic hydroxyl groups; the course of the hydrogenation shows that auxin contains one double bond and one carbon ring; it is therefore a monocyclic trihydroxy carboxylic acid with one ethenoid link. If we call the basic hydrocarbon $C_{18}H_{36}$ *auxane*, then the growth substance is auxene-triol-acid.

A second crystalline substance of equal physiological potency was recognised in *auxin lactone* $C_{18}H_{30}O_4$. Like auxin the lactone exhibits mutarotation, which is evidently due to the attainment of an equilibrium between the acid and its lactone. A constant rotation is reached after two or three hours, and if we may utilise the results of Haworth and his collaborators by way of comparison, we can deduce the size of the lactone ring. According to these authors δ-lactones usually attain equilibrium in a few hours, whilst γ-lactones require days. We consider it therefore probable that in our case the substance is a δ-lactone. If there were hydroxyl groups in both the γ- and δ-positions, the formation of a γ-lactone would very probably be favoured, whence we conclude that there is in auxin no hydroxyl group in the γ-position (with respect to the carboxyl group).

So far we have only been able to sacrifice 126 mg. of the substance for degradation experiments. Miss Erxleben has succeeded in isolating two important oxidation products. The first oxidative attack was directed against the double bond. On treatment of 25 mg. with permanganate in sodium carbonate solution a crystalline optically active acid was obtained.

[1] *Avena sativa* = oats.

The experiment was repeated twice with the acid, and once with the lactone; we were thus able to characterise the degradation product by means of analyses, titration, and preparation of the *p*-Phenyl phenacyl ester as a dicarboxylic acid of the formula $C_{13}H_{24}O_4$.

Of course one is inclined to assume that the auxin molecule was split at the double bond, and that one of the carboxyl groups of the dicarboxylic acid was identical with that one already present as such in the auxin molecule. This assumption, however, at once creates a difficulty: since our C_{13}-acid does not contain the hydroxyl group which in auxin occurs in the δ-position relative to the carboxyl, this group must have been present in the C_5 residue removed by oxidation. If we do not wish to assume a lactone ring with more than six members, we arrive at the partial formula of Fig. 4, according to which the C_{13}-acid should be a substituted malonic acid. The acid, however, could be heated 100° above its melting point, without losing carbon dioxide. We assume therefore that *both* carboxyls of the C_{13}-acid have been

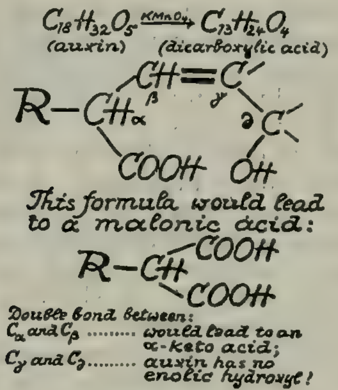


FIG. 4.

newly formed by the oxidation of auxin, whilst the 'auxin carboxyl' originally present was removed with the C_5-residue.

In order to test this hypothesis further, we oxidised *dihydro auxin* in glacial acetic acid solution with chromium trioxide. So far we could only do one experiment, with 22 mg. of substance. Fortunately we obtained besides *oxalic acid* a *neutral* product which could be converted into a crystalline *p*-nitrophenyl hydrazone, the micro-analyses of which indicate the formula $C_{13}H_{24}O$ for the oxidation product. Since it gives no aldehyde reactions it must be a *ketone*. In this oxidation also the oxygen atoms originally present in the auxin molecule have disappeared with the C_5 residue; evidently the *cyclic ketone* corresponding to the C_{13}-acid has been formed.

The simplest explanation of the results of the degradation leads to the following working hypothesis (Fig. 5):

(1) The three hydroxyl groups are not distributed over the whole molecule, but are localised in the region of five carbon atoms; one of these five carbon atoms belongs to the carboxyl group.

(2) In the C_5-residue there is probably a hydroxyl group in the δ-position with respect to the carboxyl, whilst the γ-position is free of hydroxyl. The two other hydroxyls would then have to be in positions α and β.

(3) The ring of auxin is not terminal; it probably contains the double

bond, and it is at a carbon atom bearing this double bond that the C_5-residue is attached.

I will not present here probable formulæ for auxin which may seem rather premature ; but I will limit myself to a few formulæ which by now have

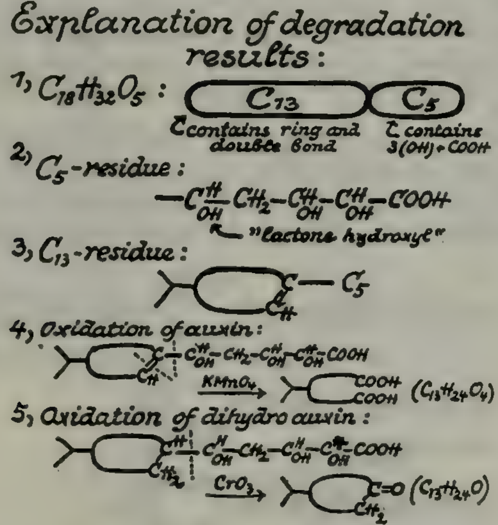


FIG. 5.

already been disproved but nevertheless afford an illustration of the constitutional problem. Attention may first be called to the formula of chaulmoogric acid (Fig. 6). Like auxin this vegetable acid contains 18 carbon atoms, a double bond, and a ring ; there is, however, no relationship, for chaulmoogric acid has a terminal ring. Of the formulæ in Fig. 7, the first may be excluded with certainty since 4-*n*-heptyl cyclo hexanone, synthesised by Mr. Picard, is not identical with our ketone. The exact comparison of β-*n*-heptyl adipic acid, which was also synthesised, has not yet been made,

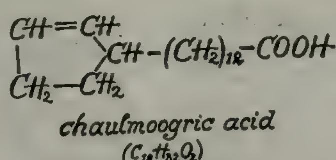


FIG. 6.

since the synthetic acid has not yet been resolved into its enantiomorphs ; the same applies to α-*n*-heptyl adipic acid synthesised by Mr. Koningsberger. The following experiments showed us, however, with certainty that our C_{13}-acid has a different structure, for we submitted the two adipic acids, in quantities of 20 mg., to Blanc's reaction and could obtain definitive evidence of the formation of pyrolytic ketones. The degradation product however furnished in a similar experiment no such ketone, but an *acid anhydride*. The formation of an anhydride in Blanc's reaction is quite general with glutaric acids, exceptional with adipic acids. Hence we consider it to be *more probable* that our degradation product is a glutaric acid and that auxin contains a *five ring*. Numerous substituted glutaric acids

are being synthesised in my laboratory. If our working hypothesis is in the main correct, the problem consists further chiefly in determining the way in which the ultimate residue of C_8 is attached to the glutaric acid and to the corresponding cyclopentene ring. Perhaps we can obtain further insight into the constitution of auxin by the syntheses of octyl glutaric acids and dibutyl glutaric acids which are in progress ; in this connection we are especially concerned with isoprene as a possible unit. We shall of course also utilise X-ray analyses, and we sincerely hope that it will not be necessary to synthesise and resolve all the 1,200 substituted glutaric acids containing 13 carbon atoms !

Although it was of course self-evident that we should first try to isolate the vegetable growth substance from the most favourable source, we were conscious from the very beginning that its isolation from *vegetable* sources should next be attempted. Our whole experience indicated that the reac-

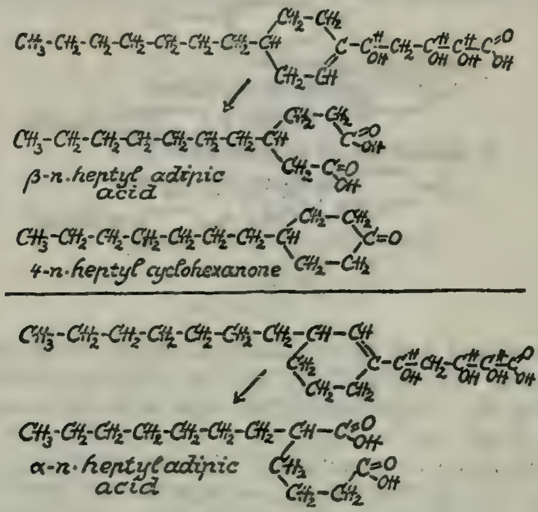


FIG. 7.

tion of Went is a strictly specific test, and it seemed likely that the active substances from various sources were identical or very closely related. But recently such predictions require, more than ever, experimental proof, for in the case of the *follicular hormone* (œstrine) it has been found that the ' lock ' can be opened not only by the classical ' key,' but also, more or less easily, by rough copies, or even by skeleton keys.

My collaborator, Kostermans, has undertaken the difficult task of isolating the vegetable growth substance from yeast, which requires a concentration of about 500,000-fold. Miss Erxleben has already succeeded within the last few months in obtaining active crystalline material from other vegetable sources, first from *maize germ oil* and then from *malt*. Both these materials are very closely related to the coleoptiles of oats, in which the growth substance was first discovered. Although specially favourable samples were used, the maize oil required a 300,000-fold concentration, malt one of 100,000-fold ; the procedure employed was essentially that worked out for urine. Both from maize oil and from malt *two* active crystalline substances were obtained. The first was found, by means of its melting point, mixed melting point, analyses, and physiological action, to be *identical* with auxin isolated from urine. The second crystalline substance melted 13°

lower than auxin; according to its very probable formula $C_{18}H_{30}O_4$ it is isomeric with auxin-lactone, from which it differs however completely, already by its acid nature. A close relationship to auxin must, however, be assumed on account of various chemical properties; the physiological activity is of the same order of magnitude as that of auxin and its lactone round about 50,000 millions A.U. per gram. Within the last few months we have prepared 120 mg. of the new crystalline substance which we will designate as *auxin-b*; the substance first isolated from urine will henceforth be called *auxin-a*. Of the four oxygen atoms of auxin-*b*, two belong to a carboxyl and one to a hydroxyl group. The course of the mutarotation once more indicates that this hydroxyl is in a δ-position with reference to the carboxyl. The fourth oxygen is present as a *ketogroup*: auxin-*b* yields a crystalline *semicarbozone* and on treatment with methyl alcoholic hydrogen chloride forms a crystalline lactone of the *dimethyl acetal*. Finally, we can also give some indication of the position of the carbonyl group relative to the carboxyl. At its melting point auxin-*b* rapidly evolves carbon dioxide and passes into a neutral substance. As far as we can see this is only compatible with the assumption that auxin-*b* is a β-*ketonic acid* (Fig. 8); we are surprised that the substance can nevertheless be isolated. We have not

Auxin-a $C_{18}H_{32}O_5$
(auxene-tri-ol-acid)
$$R-\underset{OH}{CH}-CH_2-\underset{OH}{CH}-\underset{OH}{CH}-C{\genfrac{}{}{0pt}{}{\nearrow O}{\searrow OH}}$$

Auxin-b $C_{18}H_{30}O_4$
(auxene-ol-on-acid)
$$R-\underset{OH}{CH}-CH_2-CO-CH_2-C{\genfrac{}{}{0pt}{}{\nearrow O}{\searrow OH}}$$

FIG. 8.

yet succeeded in transforming one of the auxins into the other, but we have been able to oxidise auxin-*b* with permanganate to the same dicarboxylic acid with 13 carbon atoms which we had already obtained from auxin-*a*; the double bond must therefore be in the same position in both molecules. Finally, it should be mentioned that the crystals of both auxin-*a* and of auxin-*b* completely lose their physiological action on keeping for some months. All these facts make it certain that our two auxins are very closely related.

The occurrence of auxin-*a* in urine brought this vegetable hormone ('phytohormone') also into the realm of animal physiology. We have given considerable attention to the problems arising in this connection, but I can only mention the results here very briefly. Adults excrete about 2 mg. of auxin-*a* per day, independently of age or sex. Urine excreted a few hours after a meal has the highest auxin content (Fig. 9). During a day of fasting less auxin is eliminated and the characteristic 'auxin peak' does not appear. We have tested various diets and found that after ingestion of glucose, starch, or egg white *no* auxin peak appears, but that such a peak does appear after ingestion of salad oil (arachis oil; Fig. 10), and butter (Fig. 11). Fats and oils contain the auxins in a free or in an esterified form. A hydrogenated coco-fat, in which the auxins had been modified by reduction and inactivated as regards plants, produces *no* auxin peak (Fig. 11). The auxin peaks do not therefore arise indirectly after ingestion of fats. A large part of the eliminated auxin is derived from the fats of the food.

Presumably there are also in food unknown precursors or derivatives of the auxins. So far we have been unable to isolate auxin-*b* from urine; we must therefore conclude that the auxin-*b* ingested with the food is trans-

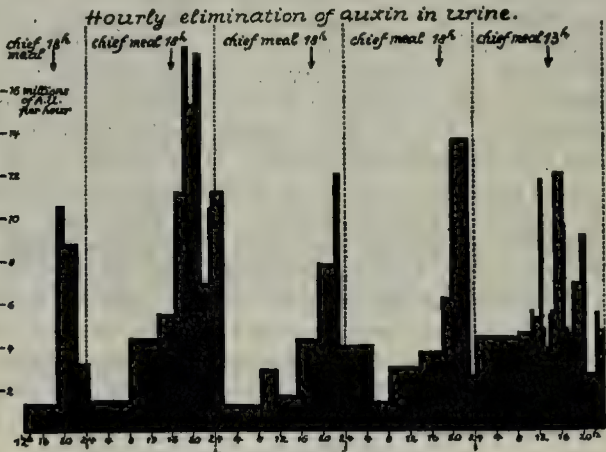


FIG. 9.

formed in the organism into auxin-*a*. In this connection we may recall the relationship between methyl glyoxal and glycerol, and that between the follicular hormone and its hydrate.

The isolation of auxin-*b* has of course raised many new physiological questions. At present I would merely mention that according to experiments due to Dr. Albert Fischer of Copenhagen, the growth of fibro-blasts of

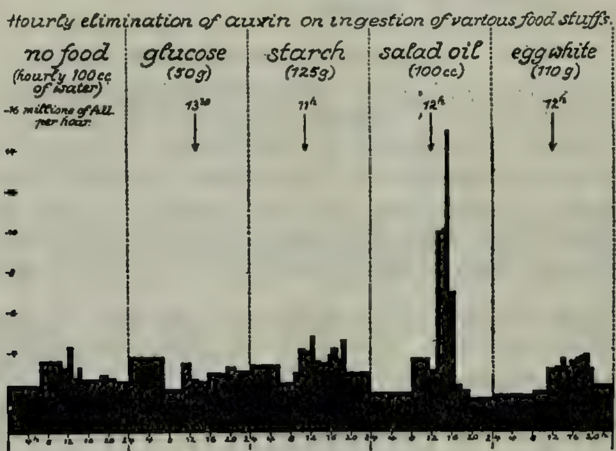


FIG. 10.

the heart is not accelerated when auxin-*a* or auxin-*b* is added to the nutritive medium of tissue cultures. So far we have obtained no indication that our vegetable growth hormones have also the function of animal hormones. Rather is it a question whether the auxins, which are so important to the plant, have for the animal organism the character of vitamins, or whether they are merely substances indifferent to the animal body.

Finally, I would like to refer to certain experiments which are really a

'by-product' for us chemists, but are of great biological interest. The potency of 50,000 million A.U. per gram of our phytohormones is only an average value ; the actual potency varies from day to day, and in the course of time we have observed with standard solutions all degrees of potency between about 10,000 million and 100,000 million A.U. per gram. Our suspicion has been more and more strengthened that these large variations are not due to experimental error but to unknown external causes, which can even exert their influence in our dark laboratory kept at constant temperature and humidity. We paid special attention to the various atmospheric conditions, but no certain relationship could be deduced even from observation extending over several months. My colleague, Prof. Went, informs me that the possibility of such unknown influences of the weather has often been canvassed in vegetable physiology, but that all experiments aiming at

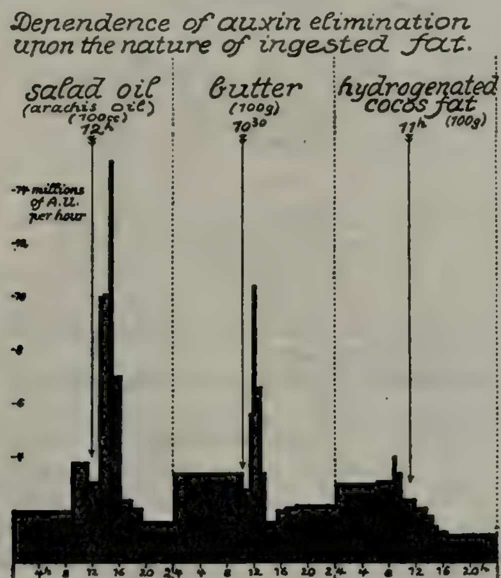


FIG. 11.

the discovery of definite relationships, e.g. to 'atmospheric electricity,' have failed.

We did not make any progress until we undertook the examination of the potency of the auxins at hourly intervals during periods of 24 hours. This examination was more easily planned than carried out, but the skill and perseverance of my collaborator, Dr. Haagen-Smit, overcame all technical difficulties. Whilst we normally carry out tests on 300 to 400 seedlings per day, up to 1,500 seedlings had to be examined on the following important experimental days. Since the age of the seedlings in the test reaction is not a matter of indifference, we use them exactly 88 hours after sowing. The determinations of potency during the 24 hours of an experimental day were therefore only valid, when the sowing had likewise taken place at hourly intervals, four days previously. The results of the experiments are represented in Figs. 12 and 13, in chronological sequence. I would here summarise them by a few empirical rules :

We found that in the *morning hours*—not always but mostly—there occurs a pronounced maximum of potency. Thus, for instance, one and the same

auxin solution was, on December 17th, at 4 A.M., six times as active as in the forenoon of the preceding day. A potency which we had previously

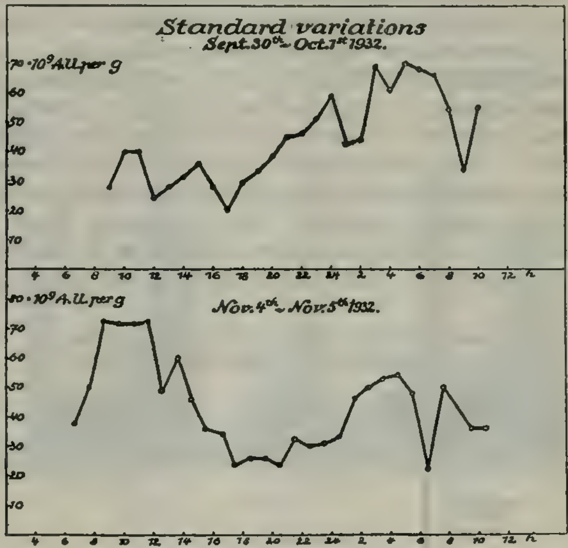


FIG. 12.

regarded as characteristic of an individual day, in reality therefore applies to the actual hour of the experiment.

After consultation with Prof. Ornstein of the Physical Institute and his

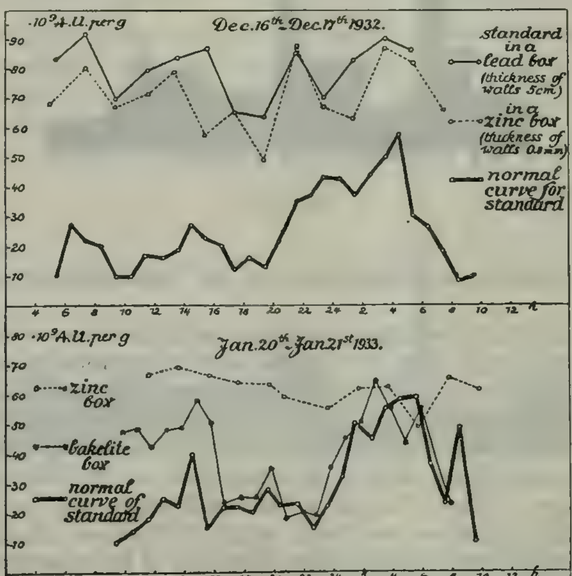


FIG. 13.

assistant, Mr. Jan Went, we carried out further series of experiments in order to elucidate the changes in the potency of our standard. We tested the potency of auxin solutions on seedlings grown in a Faraday cage, in

metal boxes, and in bakelite boxes, and also kept in these containers during the twenty-four hours of the actual experimental day. We, of course, took care to have the same temperature and humidity inside the boxes as in our laboratory.

Now whilst the action of the auxin on the 'cage seedlings' and 'bakelite seedlings' was pretty much the same as that on the control seedlings outside, the seedlings in the metal boxes gave us quite a different curve of potency; this curve is on the average higher and the percentage variations are much smaller. The difference is all the more striking if we bear in mind that the seedlings have to be removed from the boxes during a short interval each time they are manipulated in carrying out the test.

What conclusions can be drawn from these experiments? The essential difference between metal and bakelite boxes is doubtless that in the former, that is inside a conductor, an *electrical field* is *abolished* and *atmospheric ions* are *eliminated*. The electrical field is also abolished inside the cage, but the latter does not completely eliminate atmospheric ions. No difference could be observed between zinc walls of 0·8 mm. and leaden ones of 5 cm. in thickness. The leaden box was suggested by our physical advisers with a view to the detection of a possible influence of cosmic rays.

It was of course our aim to influence the susceptibility of the seedlings to auxin solutions *at will*, by physical means. We were as yet unable to do this by definite electrical fields and a supply of atmospheric ions, but we succeeded by means of an experimental arrangement suggested by a conversation with Prof. Pohl of Göttingen. On the supposition that the observed variations were caused by very weak electrical currents in the seedlings, we have artificially produced a potential difference in them. For this purpose (Fig. 14) a moist silk thread was fastened to the agar block and then, for instance, connected to the positive pole of the source of current, while the plant trough was joined to the negative pole, or conversely. We had for example a potential difference of 80 millivolts per cm. and a current of 0·0008 milliamperes. What was the effect?

The auxins are acids. When the silk thread was connected with the negative pole, the transport in a basal direction of the physiologically active auxin anion is accelerated. In this case we could increase the potency of the standard solutions—that is to say the susceptibility of the plants—to 120,000 million A.U. per gram. On commutation the transport in a basal direction is inhibited and the susceptibility can be lowered to 10,000 million A.U. per gram. Finally, we may point out that atmospheric conductibility in a closed space is also known to be subject to diurnal variations. We may therefore safely conclude that the normal variations of susceptibility are also due to changes in the electrical conditions of the air.

It will be the task of the botanists to deduce from these experiments conclusions concerning the finer mechanism of vegetable tropisms. But we think that our experiments may also be of interest to medical investigators, especially since the effect of unknown climatic influences on disease and the unequal distribution of births and deaths during a period of 24 hours has of late been the subject of renewed discussion. The physician, however, will have a more difficult task than ourselves, for man is a less suitable 'experimental object' than are our seedlings.

Finally, I should like to express my gratitude for the kind invitation to address the British Association at Leicester on the subject of the auxins. It has given me great pleasure to accept this invitation, since it offered to me a welcome opportunity of making the acquaintance of British colleagues.

REFERENCES TO PUBLICATION OF COMMUNICATIONS TO THE SECTIONS

AND OTHER REFERENCES SUPPLIED BY AUTHORS.

The titles of discussions, or the names of readers of papers in the Sections (pp. 427–577), as to which publication notes have been supplied, are given below in alphabetical order under each Section.

References indicated by ' cf.' are to appropriate works quoted by the authors of papers, not to the papers themselves.

General reference may be made to the issues of *Nature* (weekly) during and subsequent to the meeting.

Section A.

Astbury, W. T.—*Nature*, **132**, 3337, p. 593, Oct. 14 (1933); to appear in *Phil. Trans. Roy. Soc.*; cf. *ibid.*, A, **230**, 75 (1931); *Nature*, **126**, 913 (1930); *Journ. Text. Inst.*, **213**, T17 (1932); *Trans. Far. Soc.*, **29**, 193 (1933); *Journ. Soc. Dyers & Colourists*, **49**, 168 (1933); ' Fundamentals of Fibre Structure ' (Astbury), O.U.P. (1933).

Bloch, O. F.—Cf. *Journ. Roy. Soc. Arts*, **81**, Feb. 3 (1933).

Church, Maj. A. G.—*Nature*, **132**, 3335, p. 502, Sept. 30 (1933).

Cockcroft, Dr. J. D.—*Proc. Roy. Soc.*, **137**, p. 229.

Dee, P. I.—*Proc. Roy. Soc.*, A, **141**, p. 733 (1933).

Eddington, Sir A.—*Times*, Sept. 13 (1933).

Franklin, C. H. H.—To appear in *Nature*; may appear in *Journ. Phys. Soc.*

Lee, H. W.—*Engineering*, **136**, 3539, p. 533, Nov. 10 (1933).

McCrea, Dr. W. H.—*Monthly Notices, R.A.S.*, **92**, pp. 7–12, Nov. (1931).

McVittie, D. G. C.—*Monthly Notices, R.A.S.*, **92**, pp. 7–12, Nov. (1931).

Miller, Prof. Dayton C.—*Reviews of Modern Physics*, Aug. (1933); short account to appear in *Nature*.

Milne, Prof. E. A.—Cf. *Nature*, July 2 (1932); *Zeitschr. für Astrophys.*, **6**, p. 1 (1933); *Monthly Notices, R.A.S.*, Supp. Notice, **93** (1933).

Oliphant, Dr. M. L.—*Proc. Roy. Soc.*, Sept. (1933); *Nature*, Sept. 16 (1933); cf. *Proc. Roy. Soc.*, A, 141, pp. 259 and 722 (1933).

Preston, Dr. R. D.—*Nature*, **132**, 3337, p. 594, Oct. 14 (1933).

Regener, Prof. Dr. E.—*Nature*, **132**, 3340, p. 696, Nov. 4 (1933); *Times*, Sept. 12 (1933); to appear in *Zeitschr. für Physik*.

Rutherford of Nelson, Lord.—*Proc. Roy. Soc.*, Sept. (1933); *Nature*, **132**, 3333, p. 432, Sept. 16 (1933); *Times*, Sept. 12 (1933).

Simons, Dr. L.—*Proc. Phys. Soc.*, **45**, pt. 2, 247, p. 266, March 1 (1933).

Smart, E. H.—*Proc. Phys. Soc.*, **45**, pt. 2, 247, p. 266, March 1 (1933).

Speakman, Dr. J. B.—*Nature*, **132**, 3337, p. 594, Oct. 14 (1933).

Taylor, W.—*Engineering*, **136**, 3539, p. 533, Nov. 10 (1933).

Thewlis, J.—Expected to appear in *Brit. Dental Journ.*, and *Phil. Mag.*; cf. *Brit. Journ. Radiol.*, **5**, p. 353 (1932); *Brit. Dental Journ.*, **53**, p. 655 (1932); *Nature*, **132**, 3337, p. 594, Oct. 14 (1933).

Vegard, Prof. L.—*Nature*, **132**, 3339, p. 682, Oct. 28 (1933); *Engineering*, **136**, 3537, p. 470, Oct. 27 (1933); cf. *Geophys. Publ. Oslo*, **9**, 11 (1932); *Terr. Magn.*, Sept. (1932); *Geophys. Publ. Oslo*, **10**, 4 (1933); *ibid.*, **10**, 5 (1933).

Walton, Dr. E. T. S.—*Proc. Roy. Soc.*, **137**, p. 229.

Papers in Technical Physics, A‡.

Beetlestone, A.—*Engineering*, **136**, 3537, p. 471, Oct. 27 (1933).

Bradley, H.—On 'Testing of flexible sheet materials,' to appear in *Journ. Internat. Soc. Leather Trades' Chemists*, Feb. (1934).

Burch, C. R.—*Engineering*, **136**, 3537, p. 470, Oct. 27 (1933).

Cockcroft, Dr. J. D.—*Proc. Roy. Soc.*, **136**, p. 619.

Cramp, Prof. W.—*Electrician*, **111**, 2890, p. 471, Oct. 20 (1933); *Engineering*, **136**, 3537, p. 471, Oct. 27 (1933).

Goodlet, B. L.—*Engineering*, **136**, 3537, p. 471, Oct. 27 (1933).

Randall, J. T.—*Nature*, **132**, 3336, p. 574, Oct. 7 (1933); *Times*, Sept. 12.

Spiers, Dr. C. H.—*Leather Trades' Rev.*, Oct. 4 (1933); may appear in *Journ. Internat. Soc. Leather Trades' Chemists*.

Department A*.

Du Val, Dr. P.—Cf. *Journ. Lond. Math. Soc.*, **8**, pp. 11 and 199; further papers to appear in later issues.

Green, H. G.—Cf. *Journ. Ecole Polytechnique*, **31**, Serie II.

Hodge, W. V. D.—*Math. Gaz.*, Jan. (1934); *Journ. Lond. Math. Soc.*, **8**, 4; to appear in *Proc. Lond. Math. Soc.*

Offord, Dr. A. C.—On ' Fourier transforms,' to appear in *Proc. Lond. Math. Soc.* On ' Hankel transforms,' may appear in *Ann. of Maths*.

Department A†.

Best, A. C.—May appear as *Geophys. Memoir*.

Lockyer, Dr. W. J. S.—*Monthly Notices, R.A.S.*, **85**, p. 580 (1925); *ibid.*, **86**, p. 474 (1926); *ibid.*, **93**, p. 362 (1933); *ibid.*, **93**, p. 619 (1933).

McVittie, Dr. G. C.—*Monthly Notices, R.A.S.*, **93**, pp. 325–339, March (1933).

Section B.

Tanning, discussion.—To appear in *Journ. Internat. Soc. Leather Trades' Chemists*, Feb. (1934); *Engineering*, **136**, 3539, p. 526, Nov. 10 (1933).

Bergmann, Prof. Dr. M.—*Journ. Internat. Soc. Leather Trades' Chemists*,

Oct. (1933); *ibid.*, Feb. (1934); cf. *ibid.*, 244 (1931) and 239 (1931); *Naturwissenschaften*, **18**, 114 (1930); *Biochem. Zeitschr.*, **250**, 568 (1932).

Butenandt, Prof. A.—*Nature*, **130**, 3276, p. 238, Aug. 13 (1932); *Ber. d. Deutschen chem. Gesellschaft*, **66**, 601 (1933); *Zeitschr. für physiol. Chem.* (1933); *Naturwiss.*, 49 (1933).

Dodds, Prof. E. C.—Cf. *Lancet*, 1107 (1928); *Biochem. Journ.*, **22**, 6, 1526 (1928); *Journ. Obstet. & Gynæcol. of Brit. Empire*, **36**, 1 (1929); *Journ. Physiol.*, **68**, 4, Jan. 27 (1930); *Lancet*, p. 683, March 29 (1930); *ibid.*, **1**, p. 1390, June 28 (1930); *Biochem. Journ.*, **24**, 4, p. 1031; *Journ. Obstet. & Gynæcol. of Brit. Empire*, **37**, 3, p. 447; *Journ. Physiol.*, **83**, 2, Oct. 22 (1931); *Amer. Journ. Obstet. & Gynæcol.*, **22**, 4, p. 520, Oct. (1931); *Proc. Roy. Soc. Medicine*, Jan. 16 (1932); *Nature*, **131**, p. 56, Jan. 14 (1933); *Naturwissenschaften*, Feb. (1933); *Journ. Soc. Chem. Industry*, **52**, 12, March 24 (1933); *Chem. & Industry*, no. 13, pp. 287–291, March 31 (1933).

Freudenberg, Prof. K.—To appear in *Journ. Internat. Soc. Leather Trades' Chemists*, Feb. (1934); cf. 'Tannin, Cellulose, Lignin' (Freudenberg), Springer, Berlin (1933).

Haslewood, G. A. D.—*Chem. and Industry*, **51**, 277T.

Humphreys, Dr. F. E.—To appear in *Journ. Internat. Soc. Leather Trades' Chemists*, Feb. (1934).

Linstead, Dr. R. P.—Expected to appear in extended form in *Journ. Chem. Soc.*

Lloyd, Dr. D. Jordan.—To appear in *Journ. Internat. Soc. Leather Trades' Chemists*, Feb. (1934).

Maitland, Dr. P.—To appear in *Journ. Internat. Soc. Leather Trades' Chemists*, Feb. (1934).

Phillips, Dr. H.—To appear in *Journ. Internat. Soc. Leather Trades' Chemists*, Feb. (1934); cf. *ibid.*, **15**, 465 (1931); *ibid.*, **16**, 345 (1932).

Robertson, Dr. J. M.—*Proc. Roy. Soc.*, A, **140**, p. 79 (1933); *ibid.*, **141**, p. 594 (1933); and subsequently.

Thompson, F. C.—To appear in *Journ. Internat. Soc. Leather Trades' Chemists*, Feb. (1934).

Section C.

Dollar, A. T. J.—*Geol. Mag.*, **70**, pp. 479–480, Oct. (1933); cf. *ibid.*, **69**, pp. 265–268 (1932); *Report Brit. Assn.* (1932).

Eastwood, T.—*Colliery Guardian*, p. 531, Sept. 22 (1933); cf. *Mem. Geol. Survey* (1923, 1925 and 1927).

Jones, Dr. W. R.—*Journ. Hygiene*, **33**, 3, pp. 307–329, Aug. (1933); *Engineering*, **136**, 3539, p. 527, Nov. 10 (1933).

Section D.

Beadle, L. C.—May appear in extended form in *Journ. Exp. Biol.*; cf. *ibid.*, **8**, 3, p. 211, July (1931).

Bond, Col. C. J.—To appear in *Brit. Med. Journ.*; cf. 'Genetic Significance of Hemilateral Asymmetry in the Vertebrate Organism,' William Withering Lecture, Univ. Birmingham (Bond), Lewis & Co. (1932).

Cunningham, J. T.—*Proc. Roy. Soc.*, B, **110** (1932); *Proc. Zool. Soc.*, Jan. (1933); *Nature*, June 24 and Aug. 12 (1933).

Deacon, G. E. R.—Work on South Atlantic Ocean in *Discovery Reports*, **7** (1933). Work on whole of Southern Ocean to appear in later volume.

Gates, Prof. R. Ruggles.—Summary to appear in *Nature*.

Graham, M.—To appear in *Fishery Investigations*, Series II, either **13**, 5, or **14**, 2 ; cf. *ibid*., **13**, 5, or **14**, 1.

Heron-Allen, E.—*Times*, Sept. 8 (1933).

Hurst, Dr. C. C.—*Gard. Chron.*, p. 291, Oct. 14 (1933) ; cf. ' Mechanism of Creative Evolution ' (Hurst), C.U. Press (1932).

MacLagan, Dr. S.—*Scotsman*, Sept. 12 (1933) ; expected to appear in *Proc. Roy. Soc. Edin.*

Manton, Dr. Irene.—To appear in *Zeitschrift für induktiv Abstammungs und Vererbringslehre.*

Roebuck, A.—To appear in *British Birds* or as bulletin of Midland Agricultural College ; Lincolnshire section in *Trans. Lincs. Naturalists' Union* (1933) ; cf. *British Birds*, **27**, no. 1, pp. 4–23, June (1933).

Russell, F. S.—Cf. *Journ. Marine Biol. Assn.*, **13–18**. One further paper expected to appear.

Watson, Prof. D. M. S.—*Times*, Sept. 9 (1933).

Wigglesworth, Dr. V. B.—Cf. *Journ. Exp. Biol.*, **8**, pp. 411–451 (1931) ; *Proc. Roy. Soc.* B, **109**, pp. 354–359 (1931) ; *Quart. Journ. Micr. Sci.*, **75**, pp. 131–150 (1932) ; *Journ. Exp. Biol.*, **10**, pp. 16–26 (1933).

Section E.

Clough, Lt.-Col. A. B.—May appear in *Scot. Geog. Journ.*

Dickinson, R. E.—*Amer. Geog. Rev.* (1934) ; cf. ' Commercial Functions of Nuclei of English Conurbations,' *Sociol. Rev.* (1929).

Edwards, K. C.—*Colliery Guardian*, Sept. 29 (1933) ; cf. ' Luxembourg Studies,' Leplay Soc. (1933).

Forde, Prof. C. Daryll.—To appear in *Scot. Geog. Mag.*

Gait, Sir Edward A.—*Journ. Roy. Soc. Arts*, Oct. 20 (1933).

Gilbert, E. W.—Expected to appear in *Scot. Geog. Mag.*

Gimson, M.—*Leics. Mercury*, Sept. 7 (1933).

Peach, H. H.—*Leics. Mercury*, Sept. 7 (1933) ; *Leics. Evening Mail*, Sept. 7 (1933) ; cf. *Journ. Roy. Soc. Arts*, **78**, 4022, Dec. 20 (1929).

Steers, J. A.—Cf. *Geophys. Journ.*, Jan. (1927) ; *Trans. Norfolk & Norwich Nat. Hist. Soc.*, **12** (1925–6) ; *ibid.*, **13** (1931–2) ; ' Scientific handbook on Scolt Head Island ' (editor, J. A. Steers), in preparation.

Section F.

Florence, Prof. P. S.—*Industry Illustrated*, Oct. (1933) ; Chap. VII of ' Logic of Industrial Organisation ' (Florence).

Plant, Prof. A.—*Financial News*, Sept. 9 (1933).

Walker, G.—May appear in *Economica* ; cf. *Econ. Journ.*, June (1933).

Wilson, Sir Arnold T.—Cf. ' The Suez Canal ' (Wilson), O.U. Press (1933).

Department F*.

Annan, Prof. W.—*Accountants' Mag.* (Edinburgh), Nov. (1933); cf. *Accountant*, Aug. 19 (1933); *Proc. Internat. Congress on Accounting* (Knickerbocker Press, New York, 1929); *Accountants' Mag.*, Nov. (1927); *ibid.*, Jan. (1927).

Armstrong, Dr. E. F.—*Engineer*, p. 254, Sept. 15 (1933).

Crowden, G. P.—*Lancet*, pp. 665–666, Sept. 16 (1933); *Industry Illustrated*, pp. xv-xviii, Sept. (1933); *Industrial Welfare & Personnel Management*, Sept. (1933); *Electrician*, Sept. 22 (1933); *Nature*, p. 684, Oct. 28 (1933); to appear in full in *Human Factor*.

Neal, L.—*Lecture Recorder*, **3**, 3, Oct. (1933); to appear in *Industry Illustrated*; cf. 'Retailing and the public' (Neal), Allen & Unwin.

de Paula, F. R. M.—*Industry Illus.*, Sept. (1933); *Accountant*, Oct. 7 (1933).

Urwick, Maj. L.—Published by Management Library; to appear in extended form as 'Organisation as a technical problem' (Urwick), McGraw Hill.

Section G.

Adeney, Prof. W. E.—*Engineering*, **136**, 3532, p. 339, Sept. 22 (1933); *ibid.*, **136**, 3535, p. 423, Oct. 13 (1933).

Arnold, R. N.—*Engineering*, **136**, 3535, p. 417, Oct. 13 (1933); *Engineer*, p. 314, Sept. 29 (1933).

Atter, H. F.—*Engineering*, **136**, 3532, p. 339, Sept. 22 (1933).

Capon, R. S.—*Engineering*, **136**, 3537, p. 475, Oct. 27 (1933); *Engineer*, p. 255, Sept. 15 (1933).

Chamberlain, J.—*Engineering*, **136**, 3530, Sept. 8 (1933); *Engineer*, p. 254, Sept. 15 (1933).

Du-Plat-Taylor, M.—*Engineering*, **136**, 3533, p. 372, Sept. 22 (1933); *ibid.*, **136**, 3533, p. 369, Sept. 29 (1933); cf. 'Reclamation of land from sea' (Du-Plat-Taylor), Constable (1930).

Gouldbourn, J.—Privately printed; *Engineering*, **136**, 3533, p. 368, Sept. 29 (1933).

Haworth, J.—*Engineering*, **136**, 3531, p. 284, Sept. 15 (1933); *ibid.*, **136**, 3532, p. 340, Sept. 22 (1933).

Leonard, Dr. A. G. G.—*Engineering*, **136**, 3532, p. 339, Sept. 22 (1933); *ibid.*, **136**, 3535, p. 423, Oct. 13 (1933).

Lupton, H. R.—*Engineering*, **136**, 3532, p. 340, Sept. 22 (1933), and later issue.

McKay, A. M.—*Engineering*, **136**, 3535, p. 417, Oct. 13 (1933); and later issue; *Engineer*, p. 314, Sept. 29 (1933).

Maughan, W.—*Engineering*, **136**, 3533, p. 368, Sept. 29 (1933); *Daily Express*, Sept. 13 (1933).

Taylor, W.—*Engineer*, p. 254, Sept. 15 (1933).

Vokes, F. C.—*Engineering*, **136**, 3531, p. 317, Sept. 15 (1933); *ibid.*, **136**, 3532, p. 340, Sept. 20 (1933); *Surveyor*, Sept. 22 (1933); cf. *Proc. Inst. C.E.*, **226**, pt. 2, paper no. 4660 (1927–8); *World Power*, April (1933).

Walker, Prof. Miles.—*Engineering*, **136**, 3532, p. 326, Sept. 22 (1933); *Modern Transport*, **30**, 757, p. 5, Sept. 16 (1933); *Engineer*, p. 292, Sept. 22 (1933).

Watson, J. D.—*Engineering*, **136**, 3531, p. 283, Sept. 15 (1933); *ibid.*, **136**, 3532, p. 339, Sept. 22 (1933).

Wilson, W.—To appear in *Engineering*; *Engineer*, p. 255, Sept. 15 (1933).

Section H.

Cardinall, A. W.—Cf. 'Nations of Northern Territories of Gold Coast' (Cardinall, 1920); 'In Ashanti and Beyond' (Cardinall, 1927); 'Tales Told in Togoland' (Cardinall, 1931); 'The Gold Coast, 1931' (Cardinall, 1932).

Childe, Prof. V. Gordon.—To appear in extenso in *Ancient Egypt and the East*; summary to appear in *Nature*.

Davies, O.—To be extended in book form; cf. 'Roman and Medieval Mining,' *Trans. Inst. Mining and Metall.* (1933–4).

Dollar, A. T. J.—*Man*, **33**, p. 166, Oct. (1933); *Ilfracombe Chron.*, Sept. 15 (1933).

Evans-Pritchard, Prof. E. E.—To appear in *Man*.

Forde, Prof. C. Daryll.—Summary to appear in *Man*; cf. 'Ethnography of the Yuma Indians' (Forde), Univ. California Press (1931).

Fox, Dr. C.—Cf. 'Personality of Britain: Its Influence on Inhabitant and Invader in Prehistoric and Early Historic Times' (Fox), Nat. Museum of Wales.

Gates, Prof. R. Ruggles.—*Journ. Roy. Anthrop. Inst.*, Jan. (1934).

Hornell, J.—To appear in *Journ. Roy. Anthrop. Inst.*; cf. *Man*, 55 (1919); *ibid.*, 67 (1920); *Mariner's Mirror*, **19**, pp. 439–445 (1933).

Hutton, Dr. J. H.—Summary to appear in *Nature*; may appear in *Current Science* (Bangalore).

Jackson, K. H.—In part in *Bull. Board of Celtic Studies*, Nov. (1933); remainder expected to appear in *Man*.

Nadel, Dr. S. F.—Cf. *Musical Quarterly* (New York), **16** (1930); *Erdball* (Berlin) (1931); *Zeitschr. Wien Akad. Wissensch.* (1931); 'Georgische Gesänge' (Nadel), Lautabteilung, Berlin (1933); 'Messungen an Raukasischen Grifflochpfeifen' (Nadel), Anthropos (1934).

Palmer, Sir Richmond.—May appear in *Journ. Roy. Anthrop. Inst.*

Pokorny, Prof. J.—*Zeitschr. für celtische Philologie*, **20** (1933); to appear in *Journ. Roy. Anthrop. Inst.*

Rattray, Dr. R. S.—*Times*, Sept. 12 (1933).

Roth, G. K.—*Man*, 170, Oct. (1933); expected to appear in detail in *Journ. Roy. Anthrop. Inst.*; cf. *Man* (1933), articles no. 49, 67 and 167.

Section I.

Bedford, Dr. T.—To appear in *Journ. of Hygiene*.

Burn, Prof. J. H.—Cf. *Quart. Journ. Pharm. Pharmacol.*, **2**, 187 (1930); *Journ. Pharmacol. Exp. Ther.*, **46**, 75 (1932); *Journ. Physiol.*, **75**, 144 (1932).

Dufton, A. F.—To appear in *Journ. of Hygiene.*

Edridge-Green, Dr. F. W.—Cf. ‘ Physiology of Vision ’ (Edridge-Green, 1920) ; ‘ Science and Pseudo-Science ’ (Edridge-Green, 1933).

Feldberg, Dr. W.—*Journ. Physiol.*, Nov. 18 (1933) ; in part in *Pflügers Archiv*, **23**, remainder to appear in *Journ. Physiol.*

Harris, Dr. L. J.—Cf. *Science Progress*, **13**, 68 (1928) ; *Lancet*, **1**, 1031 (1932) ; *Biochem. Journ.*, **23**, 206 (1929) ; *ibid.*, **25**, 367 (1931).

Hunter, Dr. D.—Cf. *Lancet*, **1**, 897, 947, 999 (1930) ; *Brit. Journ. Surg.*, **19**, 203 (1931–2).

Kay, Dr. H. D.—Cf. *Physiol. Rev.*, **12**, pp. 384–422 (1932) ; *Journ. Nutrition*, **6**, pp. 313–324 (1933).

Robison, Prof. R.—Cf. work to appear in *Biochem. Journ.* ; ‘ Herter Lectures ’ (Robison), New York Univ. Press (1932).

SECTION J.

Correlation, discussion on methods.—*Nature*, Oct. 21 (1933).

Balchin, N. M.—*Journ. Nat. Inst. Indust. Psych.* ; *Industry Illus.*

Brown, Dr. W.—On ‘ Personal Influence,’ *Brit. Med. Journ.*, Sept. 16 (1933).

Cattell, Dr. R. B.—*Brit. Journ. Psych.*, Jan. and July (1933).

Creed, Dr. R. S.—Expected to appear in *Nature.*

Hurst, Dr. C. C.—*Eugenics Rev.*, Jan. or April (1934) ; cf. *Proc. Roy. Soc.*, B, **112** (1932).

Piaggio, Prof. H. T. H.—To appear in extended form in *Brit. Journ. Psych.* ; *Nature*, Oct. 21 (1933) ; cf. *Brit. Journ. Psych.*, **24**, 88, July (1933).

Rodger, A.—*Journ. Nat. Inst. Indust. Psych.*, Feb. (1934) ; cf. *Brit. Journ. Educ. Psych.*, **3**, 2, June (1933).

Shaw, Miss A. G.—*Labour Management*, Oct. (1933) ; *Engineer*, p. 254, Sept. 15 (1933).

Tolman, Prof. E. C.—Cf. *Psych. Rev.*, **40**, pp. 60–70, Jan. (1933) ; *ibid.*, **40**, pp. 246–255, May (1933) ; *Univ. Calif. Publ. Psych.*, **4**, 5, pp. 71–89, Sept. (1929).

Thouless, Dr. R. H.—Expected to appear in *Brit. Journ. Psych.* ; cf. *ibid.*, **21**, pp. 339–359 ; **22**, pp. 1–30 ; **22**, pp. 216–241.

Valentine, Prof. C. W.—To be embodied in book yet to be published.

Vernon, Miss M. D.—Expected to appear in *Brit. Journ. Psych.* (1934).

Vernon, Dr. P. E.—*Psych. Rev.*, **40** (1933) ; cf. *Eugenics Rev.*, **23**, pp. 325–331 (1932).

Wishart, Dr. J.—Cf. *Brit. Journ. Psych.*, **19**, pp. 180–187 (1928).

Wright, Dr. G. G. Neill.—To appear as part of ‘ Society and the Human Mind ’ (Wright).

SECTION K.

Ball, Prof. N. G.—Expected to appear in *New Phytologist* ; cf. *ibid.*, **32**, p. 13 (1932).

Barnes, Dr. B.—Cf. *Trans. Brit. Mycological Soc.*, **17**, p. 82 (1932).

Chattaway, Miss M. M.—To appear in *Forestry*; cf. *New Phytologist*, **31**, 119 (1932).

Cromwell, Dr. B. T.—*Biochem. Journ.*, **27**, 3, pp. 860–872 (1933).

Fisher, Prof. R. A.—To appear in *Ann. Bot.*

Gwynne-Vaughan, Prof. Dame Helen.—*Ann. Bot.*, **48**, Jan. (1934).

Hyde, F. F.—May appear in *New Phytologist* or *Ann. Bot.*; cf. *Analyst*, p. 523, Sept. (1933).

Matthews, Prof. J. R.—Cf. *Ann. Bot.* (1923, 1924, 1926).

Seward, Prof. A. C.—Expected to appear in *Ann. Bot.*

Thomas, Dr. H. Hamshaw.—To appear in *New Phytologist* (1934).

Thompson, Prof. J. McLean.—*Publications of Hartley Bot. Labs.*, **11**, Univ. Press, Liverpool, Oct. (1933).

Went, Prof. F. A. F. C.—*Nature*, **132**, 3333, p. 454, Sept. 16 (1933).

Williamson, Mrs. H. S.—*Ann. Bot.*, **48**, Jan. (1934).

Department K*.

Coke, Maj. the Hon. R.—Expected to appear in *Journ. Roy. Scot. For. Soc.*; *Journ. Roy. Engl. For. Soc.*, Jan. (1934).

Long, A. P.—Expected to appear in *Quart. Journ. Forestry*, Jan. (1934).

Mundt, H.—Expected to appear in *Scot. Forestry Journ.*; cf. *Communications from Congress of Nancy*, pp. 326–347 (Internat. Union Inst. For. Res.; 1932).

Orde-Powlett, Hon. N. A.—To appear in *Journ. Roy. Scot. Geog. Soc.*

Pratt, Lt.-Col. E.—*Quart. Journ. Forestry*, Jan. (1934); cf. back numbers of *Journ. Roy. Agric. Soc.*, and *Estate Mag.*

Rayner, Dr. M. C.—To appear in *Journ. of Ecology*; cf. *Forestry*, **3**, p. 26 (1929); *ibid.*, **4**, p. 65 (1930); *Empire For. Journ.*, **9**, p. 182 (1930); Reports of B.A. Cttee. on Mycorrhiza (1930, 1931, 1932).

Robertson, W. A.—*Timber Trades Journ.*, Sept. 23 (1933); to appear in *Journ. Scot. For. Soc.*

Section L.

Examinations and psychological tests, discussion.—*Journ. Educ.*, p. 666, Oct. (1933).

Barraclough, F.—*Journ. Educ.*, Oct. and Nov. (1933); *Schoolmaster*, Sept. 21 (1933).

Brierley, Prof. W. B.—*Journ. Educ.*, Nov. (1933); may appear in *Nature*.

Chamberlain, J.—*Hosiery Trade Journ.*, Oct. (1933).

Cornish, Dr. V.—*Journ. Educ.*, Nov. (1933); may appear in *Nature*.

Dale, Miss A. B.—May appear in *Journ. Educ. Psych.*

Farmer, E.—To appear in *Brit. Journ. Educ. Psych.*

Ferguson, Dr. A.—*Journ. Educ.*, Nov. (1933); may appear in *Nature*.

Gregory, Sir R.—*Journ. Educ.*, Nov. (1933); may appear in *Nature*.

Lawe, F. W.—Expected to appear in *Journ. Nat. Inst. Indust. Psych.*, *Industry Illus.*, *Journ. of Careers*.

Lewis, E. I.—*Financial News*, Sept. 11 (1933); cf. 'Making of a Chemical' (Lewis), Benn (1927).

McWilliam, A. S.—*High Peak News*, Sept. 23 (1933); cf. *Derbyshire Farmer* (1932); *Annual Reports, Rothamsted Experimental Station.*

Myres, Prof. J. L.—*Journ. Educ.*, Nov. (1933); may appear in *Nature.*

Oates, Dr. D. W.—To appear in *Journ. Educ. Psych.*; cf. *Brit. Journ. Psych.*, **19**, 1, pp. 1–30; *Forum of Educ.*, **7**, pp. 171–185; *Journ. Educ.*, Aug. (1929).

Pugh, Prof. W. J.—*Journ. Educ.*, Nov. (1933); may appear in *Nature.*

Salt, H.—*Shoe and Leather Record*, Sept. 15 (1933); *Shoe and Leather News*, Sept. 14 (1933); expected to appear in *Journ. Shoe Manufrs. Fedn.* or *Journ. Nat. Inst. Boot and Shoe Industry.*

Sandon, F.—*Journ. Educ.*, **65**, 771, p. 666, Oct. (1933); cf. *Forum of Educ.*, **2**, p. 29 (1924); *ibid.*, **4**, p. 223 (1926); *ibid.*, **3**, p. 24 (1925); *Math. Gazette*, May (1926); *Forum of Educ.*, **6**, p. 270, Nov. (1928); *ibid.*, **7**, p. 23, Feb. (1929); *Brit. Journ. Educ. Psych.*, **1**, 3, p. 296, Nov. (1931); *ibid.*, **3**, 3, p. 269, Nov. (1933).

Valentine, Prof. C. W.—Cf. 'The Reliability of Examinations' (Valentine), Univ. Lond. Press (1932).

Wickens, G. C.—Supplement to *Counter Clerk* (Assoc. Counter Clerks and Telegraphists); *Journ. Inst. Public Admin.*; supplement to *Post Year Book* (Union Post Office Workers).

Section M.

Ashby, Prof. A. W.—Expected to appear in *Welsh Journ. Agric.*, **10** 1934); cf. *Scot. Journ. Agric.*, **8**, 2 (1925).

Astill, Ald. P. F.—*Bull. 10, Imp. Bureau of Plant Genetics: Herbage Plants*, Sept. (1933).

Blackaby, J. H.—To appear in *Engineering*; cf. 'Technical Notes on Mechanised Farming, No. 1, Mole Drainage' (Blackaby), Univ. Oxf. Inst. Research Agric. Eng. (1932).

Blackwood, Dr. Janet H.—Cf. *Bulletin* 5, *Hannah Dairy Res. Inst.*, Feb. 1933).

Bridges, A.—*Bull. 10, Imp. Bureau of Plant Genetics: Herbage Plants*, Sept. (1933).

Davies, B.—*Times*, Sept. 13 (1933); *N. Wales Observer*, Oct. 5 (1933).

Davies, W.—*Bull.* 10, *Imp. Bureau of Plant Genetics: Herbage Plants*, Sept. (1933).

Dobson, A. T. A.—*Times*, Sept. 9 (1933).

Godden, W.—Cf. *Bulletin* 5, *Hannah Dairy Res. Inst.*, Feb. (1933).

Jones, M. G.—*Bull.* 10, *Imp. Bureau of Plant Genetics: Herbage Plants*, Sept. (1933).

Kay, Dr. H. D.—In part in *Journ. Dairy Res.*, **5**, 1 (1933).

Orwin, C. S.—To be incorporated in book (1934).

Wilson, Prof. G. S.—*Lancet*, p. 829, Oct. 7 (1933); cf. *Quart. Bull. Health Organisation, League of Nations*, **1**, no. 4, p. 664 (1932).

Wright, Dr. N. C.—*Scot. Journ. Agric.*, Jan. (1934).

APPENDIX

A SCIENTIFIC SURVEY OF LEICESTER AND DISTRICT

PREPARED FOR
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BY VARIOUS AUTHORS

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A SCIENTIFIC SURVEY OF LEICESTER AND DISTRICT

I.

LEICESTER IN ITS REGIONAL SETTING

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Definition of 'District'—Cultural and Natural Landscape—Satisfaction of Man's Desires in the Leicester Region—General Topography and Geology—The Grasslands—Cultural Forms of—Water Supply of—Market Harborough Area—Hunting—Upland Grasslands—Cultural Forms of—Physical Setting of—Vale of Belvoir—Cheese-making—Wold Country—Melton Mowbray Area—Keuper Marl Grassland—Arable Land in the North-east—Iron Ore Workings—Ironworks at Asfordby—Leicestershire Coalfield—Cultural Forms of—Physical Setting of—Charnwood Forest Area—Relief and Structure of—Formation of—Quarries of—Leicester—Site of—Roman Roads—Expansion of City—Different Areas in the City—Manufacturing Activities—Communications of the Region—Conclusion.

The region of which Leicester is the focal point exhibits, to a greater degree perhaps than any other area of the East Midlands, diversity in unity. The keynote of this diversity is found in the differing ways in which man has here adapted to serve his needs differing physical settings. The city of Leicester, functioning as the chief focal point—the principal collecting, distributing and organisation centre—for a series of districts located in the vicinity, is the chief unifying force operating in the area.

Before examining these districts with a view to discovering their chief characteristics and their relationships to the city it may be well to define what we have in mind by the term 'district.' It is here used to denote an area in which there is a combination or grouping of a series of more or less related phenomena which tend to repeat themselves throughout the area. It may be asked, What phenomena ? It is assumed that the phenomena referred to are those connected with man's utilisation of the physical setting in which he lives to satisfy his desires. The phenomena therefore are of two main kinds—those which make up the physical setting or

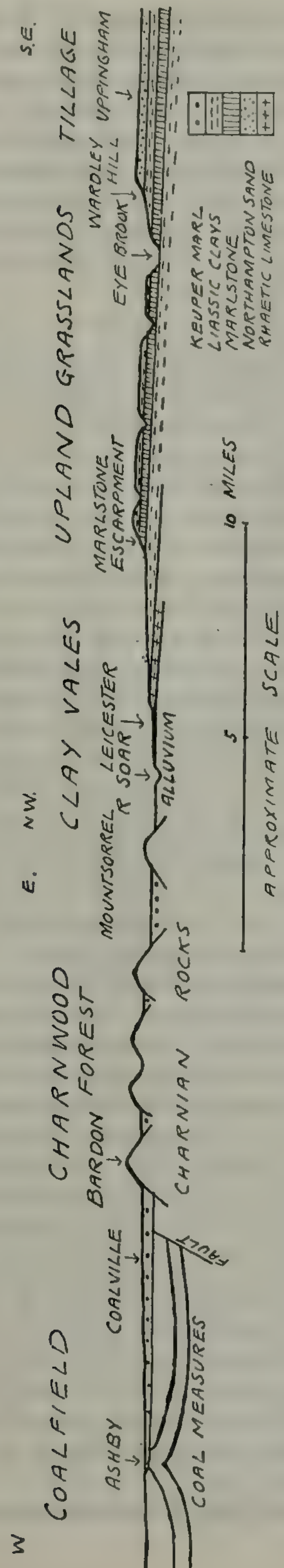
natural landscape, and those which constitute the cultural landscape or natural landscape as modified by man. The motivating force effecting this modification is taken to be the effort of man to satisfy his desires.

Man desires beef and milk. He uses the extensive grasslands of the Leicester area to raise cattle and sheep. He desires cereals and potatoes. The lighter and better-drained limestone and sandstone soils of the north-eastern part of the county provide him with a suitable area for tillage. He needs to transport his products. In the quarries of the Charnwood Forest and elsewhere he finds excellent road metal to surface his roads. He desires buildings to house and shelter his activities and their resulting products. In the marlstone at Scalford, the limestone at Croxton, and the clays of the lower grounds he finds material for his houses and villages. He needs factories in towns and cities in which to shape his products into articles suitable for consumption. In Leicester he takes leather and wool and fashions them into boots and hosiery with the aid of organisation, capital, labour, and coal from the nearby coalfield. The cities and towns require municipal government and the performance of social services for their inhabitants. Man erects suitable buildings to house these activities, constructs waterworks and power stations, and organises government. He needs recreation. He takes waste areas and converts them into the numerous playing fields, golf courses, parks and open spaces to be found in the city and countryside. He desires to gratify his æsthetic senses and preserve some of the beauties and amenities of the countryside for present and future use. He sets aside, as at Bradgate Park and Swithland Wood, beautiful scenic areas in which town and country dwellers may enjoy nature unspoilt. Through scientific methods of cultivation and production applied to his natural surroundings he obtains surpluses which he exchanges for commodities from other areas. In this fashion Leicestershire beef, milk and cheese, hosiery, boots and engineering products procure for the country and town dweller the surpluses of other regions.

These are only some of the chief relationships which exist between man and nature in the Leicester region. In all these activities man in the Leicester region makes use of his environment. His activities change from place to place throughout the region with changes in the natural environment. In each district man moulds the face of nature, and his activities are in turn moulded and modified by it. In this general geographical survey we can only touch briefly on the chief districts, with some of the cultural and natural phenomena related to man's activities, which fall within the Leicester region.

Although from the writer's point of view the most satisfactory approach to the study of a region is through an examination of the human activities in the area, it may be more helpful for the general reader to have before him a brief description of the region from the topographical and geological standpoints.

The city of Leicester is situated near the centre of the county, on the river Soar. This valley is the central topographical feature of the region. It runs roughly south-north, bending eastward in a flat bow to avoid the ancient rocky masses of the Charnwood Forest. Some miles north of the city the river Wreake enters the Soar at a right angle from the north-east.



Approximate Geological Section to illustrate Leicester in its Regional Setting.

These two valleys with their adjacent lowlands divide the region into three regions of upland—the Charnian mass to the west, the Melton Ridge to the north-east, and the Jurassic uplands to the east. Along the river valleys, between the river valleys and the uplands, and, in some cases, surrounding, penetrating, and overriding the uplands, are the great grasslands for which Leicestershire has become justly famed. To west of the Charnwood Forest the low ground is occupied by the Leicestershire coalfield stretching north-westward towards Burton. To the extreme south-east around the headwaters of the river Welland lie the rich grasslands of Market Harborough.

Broadly speaking, the underlying structure of the region is a fairly simple arrangement of clays, marlstones, sandstones, and limestones running in bands from south-west to north-east and dipping eastward. They are mostly of Triassic, Jurassic, and more recent origin. To west of the Soar valley, projecting through these younger rocks, are the coal measures forming the Leicestershire coalfield, and the ancient volcanic materials of which the rocky peaks and ridges of the Charnwood area are formed. These older materials have been partly buried in the marls of Triassic age. To east of the river Soar a low escarpment of limestone (Rhætic) forms the high ground overlooking the city. To east of it a long sweep of clay country (the Lower Lias) rises to the foot of the marlstone escarpment, beyond which lie the grassland uplands capped with clays. This marlstone country also forms the Melton Ridge whose escarpment looks down steeply on to the clay-covered grasslands of the Vale of Belvoir. The eastern part of the Jurassic uplands round Uppingham is capped with Northampton sandstone, while the eastern part of the Melton Ridge is capped partly with the Northampton sandstone and partly with the Lincolnshire limestone. From the standpoint of soils the position is complicated by widespread deposits of chalky boulder clay. This occupies the surface of much of the Melton Ridge, the Jurassic uplands, and the lowlands between the river flood plains and the upland edges.

In our brief survey of the districts which make up the Leicester region we may usefully begin with the grasslands. Our justification may be that out of the land available for crops and grazing in the county approximately five-sixths is under grass, some of which is claimed to be the best grassland in England. As nearly two-thirds of the value of English agricultural produce is derived from grassland farming, the importance of Leicestershire in this connection will be realised. The Leicestershire farmer contributes largely to the milk, cheese, beef and mutton supply of England. The Leicestershire grassland is a perennial resource which does not become exhausted as does land under crops, nor worked out as do areas from which minerals are obtained. Its fertility is maintained through the droppings of the live stock coupled with a winter rest period. Efforts are, however, being made to increase its yield. Experiments show that under favourable conditions grassland yield can be increased up to 50 per cent. with modern methods. The development of better types of grass, the application of fertiliser, and even simple harrowing, all help to increase the yield.

As we have already seen, the Vale of Belvoir to north of the Melton

Ridge, the Wreake valley to the south of it, the Soar valley in the centre of the county, the country to south of the Charnwood, and the district around Market Harborough on the headwaters of the Welland are all lowland grasslands. They possess certain features in common, and certain other features which differentiate them. These features are in part due to the physical circumstances, chiefly the soils, and in part to man. The soils are chiefly alluviums, heavy clays, or clayey loams. The clays and loams are mainly derived to west of the river Soar from the Keuper marl and boulder clay ; to east of the river from the lower and middle Lias and the chalky boulder clay. The upland grassland to east of the marlstone escarpment is capped with boulder clay and the upper Lias clay. Under the influence of the differing soils resulting from these different formations and of variations in the topography, the human activities of these grasslands and the minor cultural forms tend to vary.

The main cultural forms of the grassland are the grass fields with their herds of cattle and sheep, the farmsteads and the scattered houses of the herdsmen, the well-cared-for whitethorn hedges, the broad road spaces with their wide grass margins, the scattered villages usually smaller than those of the tilled country, and the prevalence of brick as a building material. Minor forms are the small red boards warning huntsmen of the presence of wire in the fences, and in the milk country the milk-cans are to be seen at the roadside either on the ground or on small platforms waiting collection by the milk lorries. Where tillage has given place to grassland, as in much of the chalky boulder clay country, the ridges and furrows of the old drainage system are characteristic. Along the river valleys the alluvial lands are subject to periodical flooding. This flooding keeps the land well watered and helps to renew its fertility while rendering it useless for crops. Raised footpaths on wood or iron posts are common in the flood plains of these valleys.

On the slightly higher grasslands above flood-plain level the numerous brooks and rivulets are evidence of a high water table. They ensure the land being well watered. There are some 600 of these in the county. In the areas of ridge and furrow which give alternate belts of drier and wetter land there is always, even in the driest summer, some moist herbage in the furrows. This is of considerable importance to the Leicestershire grasslands, as the county lies in that part of Great Britain which has the most Continental type of climate.

Of the subdivisions of the grasslands those around Market Harborough near the headstreams of the Welland and those along the flood plain of the river Soar are probably the richest. In the Market Harborough district the soils are mostly heavy clays or medium loams. In many parts of the district neither cake nor fertiliser is used ; the droppings of the live stock evenly spread and well trampled are adequate to maintain these lands in high condition for finishing full-grown cattle without making undue demands on the plant food in the soil. They can feed one bullock or twenty sheep to the acre, and it is said that a bullock gains in weight about 2 lb. per day on these untreated lands. As is pointed out by Mr. Hacking in his chapter on ' Agriculture ' in this survey, grassland management is here carried to a fine pitch. From this district beef and

mutton of the very best quality are sent to market. The numerous dairy herds to be seen in the fields also indicate that milk, while a secondary product in this district, is none the less produced on a fairly large scale.

Market Harborough is one of the chief hunting centres of the Midland clay vales, and therefore one of the chief hunting centres of England. In the grassland, except for dairy work, there is little to be done during the winter. Where finishing beef cattle is the main activity the cattle are usually bought in the spring, fattened on the grassland during the summer, and sold in the autumn. During the winter the grassland rests, and the beef farmer is largely free for hunting. The undulating grassland, with its stiff fences, lying between the river flood plains and the uplands, and the sharply dissected plateau country of the upland grassland, both form ideal hunting country which makes stern demands on men and horses. Its value for hunting is enhanced by the absence of tillage and the relative absence of live stock in the fields during the winter. In addition to the Market Harborough country, that around Melton Mowbray, and the Vale of Catmose in the eastern part of the area, are famous hunting centres, and it is here that we find the Quorn, the Cottesmore hunt, the Belvoir, and the Pytchley—all names famous in the annals of the chase.

North of Market Harborough and east of Leicester the country rises in a series of long grass-covered slopes to the clay-topped marlstone plateaux forming the upland grassland. In this grassland we have clearly marked that grouping and repetition of phenomena which we have assumed above to be the hallmark of a district. Its eastward boundary is Wardley Hill, near Uppingham. Within the district, with the exception of a few small and poor-looking villages, the distribution of buildings is of the dispersed type. Numerous hedges divide the area into grass fields with small farms and their associated buildings dotted about in the grassland. A few arable fields are to be seen, but they merely serve to emphasise the widespread dominance of grass. With the exception of one or two main roads, the roads up to a few years ago were poor and narrow. To-day many of these side-roads are surfaced with tarmac. By the roadside on small platforms we see milk-cans. Cattle and some sheep are in the fields. Should we pass in the winter we may see fox-hunting in full swing. We are in the country of the Quorn and the Fernie. Over a distance of eight or ten miles from Houghton-on-the-Hill to Wardley Hill we observe a repetition of the same elements of human occupancy—small farms, small houses for the herdsmen, grassfields, well-cut hedges, poor narrow side-roads—mostly gated,—one great main road, the milk-cans and their platforms, the milk lorries on the road, the small villages, the live stock in the fields, and the scattered population. It is clear that the people are mainly concerned with the tending of live stock, chiefly cattle, partly for beef, but mainly for milk, with sheep herding as a lesser activity.

The above forms of the cultural landscape concretely express man's relationship to the physical setting of these uplands. This physical setting is clear-cut and definite. It consists in the main of a repetition of simple topographical and structural elements. A series of gently undulating clay-covered marlstone plateau tops are deeply dissected by sharply cut little stream valleys with clay floors and marlstone slopes. Of these

stream valleys that of the Eye Brook is the largest. The rock layers are nearly horizontal. The weathering is typical of conditions in a relatively wet area on rocks of varying resistances. Although capable of growing corn, as is evidenced by the ridge and furrow in many of the fields, the elevation of the district, from 500 to 750 ft. above sea-level, together with the clay covering, make it unsuitable for cultivation with agricultural prices at their present levels. The district is thus for practical purposes an upland extension of the great grass vales of the Midlands. The poorer soils and the more severe climatic conditions make it less rich than the vales. As we have seen, it specialises in milk rather than beef, its holdings are smaller, its villages are poorer, and it contrasts sharply with the richer and more varied land, with its larger farms and more prosperous-looking villages, on the mixed soils and rock outcrops of Rutlandshire beyond Wardley Hill.

At the other subdivisions of the grassland we can only briefly glance. In the Vale of Belvoir to north of the Melton Ridge the clay soil is derived from the lower Lias. Here again we have the grazing of cattle and sheep, but there is a distinct tendency to specialise in the production of milk and the Stilton cheese for which the district has become famous. As far back as 1790, William Marshall, who was probably the first ecologist in this country, studied soils and the cultivation of grasses in this county from the standpoint of cheese-making. At Long Clawson, north of the Melton Ridge, there is a co-operative factory engaged in cheese-making. The boulder clay-covered Wold country to north-west and to west of the Melton Ridge, around Six Hills on the Foss Way, is a western extension of the Vale of Belvoir grass country. The grassland here is only of moderate quality, particularly where the boulder clay tends to be of a sandy or gravelly type. It makes cheese, produces milk and raises young sheep and stock. In the Melton Mowbray district to south of the ridge there is excellent grazing land, partly in the river flood plain and partly on the clay-covered land sloping up on the one side to the Melton Ridge and on the other to the upland grasslands of eastern Leicestershire. In the area south of the Charnwood and west of the river Soar, although the majority of the farms are devoted to milk production, the farming, owing to the presence of the Keuper marl with patches of sands and gravels of glacial and Triassic age, tends to be of a more mixed type. Stock is raised, and the lighter soils are devoted to such crops as wheat, oats, barley, beans, sugar-beet and mangolds.

The chief area of cultivation in the Leicester region lies north-east of Melton Mowbray. It is found in the district extending from Scalford to Knipton and Croxton on the soils derived from the marlstone, the Northampton sands and the Lincolnshire limestone. The relationship between human activities and soils is very clearly marked here. Running northward from Melton to Scalford we are on a sheet of chalky boulder clay, the heavier parts of which are under grass, while the lighter soils are tilled. Beyond Scalford we enter the marlstone rock bed. Here most of the surface is under the plough for wheat, beet, or oats. The marlstone soil is fertile, light and easily tilled. Between Knipton and Croxton a belt of the upper Lias clay crops out, forming a zone of pasture land lying

between the arable land below on the marlstone and the cultivation above on the limestone and sand.

Throughout much of this district the fields lie definitely below the level of the road. This is an indication of the working of the area to recover the iron ore present in the marlstone and in the Northampton sandstone. The ore bed, which may be up to 14 ft. in thickness, lies from a few feet down to 18 ft. below the surface. It is readily worked, in long narrow strips, by removing the surface cover, transferring the cover to the other side of the strip, calcining the ore on the spot, and shipping after about eight weeks, the time needed for calcining.[1] In this fashion the agricultural land is preserved. It is claimed that its fertility is actually increased. The general level of the land is reduced by the approximate thickness of the ore bed, though the amount of settling varies with the nature of the material forming the cover. Within our region the chief workings in operation are at Holwell, Buckminster, Branston, Knipton, Croxton, Eastwell, and Stainby to north and north-east of Melton, and at Tilton in the grassland uplands to east of Leicester. Many other workings, as at Corby, to east of our area exist. Much of the ore worked in the Leicester area goes to the furnaces at Asfordby near Melton. Here pig iron is produced and is made into castings and piping. Although some of the ores are markedly calcareous, additional limestone for fluxing purposes is obtained from the Lincolnshire limestone. Coke comes from Yorkshire, and sand for moulds from the Bunter deposits near Nottingham. Since approximately nine-tenths of the British output of iron ore comes from the Northampton Sand and the Middle Lias, these workings are of great interest. This interest is enhanced by the fact that the ironworks and also the iron workings are set in the midst of a fertile agricultural area and do a minimum of damage to the agricultural resources of that area.

Although there is little commercial connection between the iron workings and the Leicestershire coalfield, we may next glance at its main features. Standing on Bardon Hill, the highest summit of the Charnwood Forest, we look out westward over a landscape which contrasts sharply with that of the rest of our region. At our feet a steep slope runs down to the lowland. This lowland is studded with the pithead gears of the collieries and the long lines of the miners' dwellings. These are clearly visible round Coalville and vanish into the distance towards Ashby, Donisthorpe, Swadlincote, and Burton. To southward the pithead gears become fewer and give place to pasture land. The towns are small, being little better than small market towns or overgrown villages, for there is no large scale manufacturing industry here. The towns and villages are mainly marketing centres and dwelling places for the miners, together with those engaging in a few subsidiary and minor activities. The coal raised is of a quality mainly suited for household purposes, and moves out of the district for consumption elsewhere. The few industries, other than coal mining, are largely connected with the suitability of the coal-measure clays for the manufacture of drain-pipes, saggars, and firebricks.

[1] The sandstone ore is calcined on the spot to save the cost of carriage and fuel in the furnaces. The marlstone ore is not calcined at the quarries.

Below the surface the coal lies in a geological basin, the upturned edge of which is faulted against the Charnian mass on which we are standing. It was probably formed at a period when the Charnian mass was an island or series of islands in the Carboniferous swamps. The coal basin is divided into two parts or zones running from north-west to south-east parallel to the axis of the Charnwood, by an anticline running approximately through Ashby-de-la-Zouch. This central area is largely unproductive. The chief mining areas therefore lie in a western zone round Swadlincote, Moira and Donisthorpe, and in an eastern zone around Coalville and Coleorton. This latter zone is mostly concealed under a thick sheet of Triassic marls and boulder clay. Much of the western zone is heavily faulted. This adds to the difficulty and expense of working. The pithead gears, the miners' rows, the numerous small towns and overgrown villages, the absence of large scale manufacturing industry, the numerous mineral spur lines of railway, and the relatively dense population, are all forms of the cultural landscape which here reflect a definite relationship or series of relationships to the underlying geological structure and surface topography. They are the concrete expressions of man's relationship to nature in the Leicestershire coalfield.

A wholly different district is that of Charnwood Forest. Here we find some of the very few parts of the Leicester Region in which some of the natural landscape remains, though even here much of the natural forest cover has been removed and that which remains has been largely replanted. Elsewhere in the Leicester region the landscape which we see is either man-made or is nature modified by man. In the Charnwood Forest district, bare, rocky peaks, steep slopes, narrow gorges, wooded hills, patches of woodland, bracken, heather, gorse and moorland, and small streams are the chief natural features of the landscape. Of the cultural forms, grass fields and cultivation in the valley bottoms and middle slopes, scattered farmsteads with a few small villages, quarries in the hillsides, five reservoirs on the edges of the district, a few bungalows and small houses for vacationists and weekenders, one good main road and numerous improved side roads, are the more obvious.

The district consists of a mass of ancient rocks partly buried in the younger Triassic marls. The general trend of the relief is from north-west to south-east. There are four main belts of upland which break out here and there into ragged, rocky eminences—the projecting ribs of the underlying structure. These belts of upland are separated by three longitudinal depressions. They contrast sharply in their smooth outlines, their arable and pasture land, with the barren, rocky, and often tree- or bracken-covered ridges on either hand. In this contrast lies one of the great charms of the Forest area, and in it is to be found one of the reasons why the district performs the useful function of being a playground for the people of Leicestershire. The fine air available on the ridges and slopes and in some of the more elevated villages such as Woodhouse Eaves is a further reason.

Near the centre of each longitudinal depression there is a water parting. From it streams flow north-west and south-east, sometimes turning sharply at a right angle to cut their way through a bar of ancient rock—thus

forming a steep-sided gorge. One of the best-known examples of this occurs at the Brand in Colonel Martin's estate. These rock bars have helped to retain in the Charnwood valleys the red marl which gives them their fertility.

We have symmetry and great contrast as two of the marked characteristics of the Charnwood district. Both are related to the geological structure and development of the area. The geological outcrops take the form of a series of crude horseshoes placed one within the other—the open ends of the shoes being towards the north-west. The present ridges correspond roughly to the more resistant arms of the shoes, while the depressions were formed in the less resistant arms. The whole arrangement has been very much modified by severe faulting and displacement along the inside curves of the shoes. A brief picture may be given of the probable development of the present relief. A series of volcanic islands probably occupied in Archæan times what is now the site of the Forest. Much volcanic ash and lava were ejected from the volcanoes. The material cooled and solidified, becoming partially stratified in the surrounding sea. Subsequently this material, once horizontal, was ridged up into the form of a crude ellipsoidal dome. Weathering processes then broke open the dome and produced a steeply marked ridge and valley topography. This was later depressed and buried during the Triassic period in the Keuper marl. Still later erosional processes began to reveal once more the hidden landscape—a process which is still going on. The valley floors, with one exception, are still buried in the marl, to what depth it is not possible to say.

Within the Charnwood, and at places to the east and south in the lower grounds, there are numerous quarries. These are in part connected with the rock of which the Charnian mass has been built up, and in part with granites and syenites which represent upwellings of the molten magma penetrating the Charnian rocks and, in places, as a result of erosion, reaching the surface through the Keuper marl in the low grounds to the south of the Forest. Thus at Bardon Hill in the west, Groby in the south, and Mountsorrel in the east of the Charnwood, granites and related rocks are quarried for road metal and paving sets. At Enderby, Croft, Stoney Stanton, and Huncote, outcrops of syenite probably connected with the main upwellings in the Charnwood, are quarried in the midst of an otherwise purely farming country.

The Charnian reservoirs on the edge of the district, conveniently placed for gathering the heavier rainfall of the ridges, are to-day inadequate to supply the rapidly growing needs of the neighbouring population centres, such as Leicester and Loughborough, and adequate supplies are now obtained from a reservoir near the headstreams of the Derwent in the Pennine uplands. This supply Leicester shares with the cities of Sheffield, Nottingham, and Derby.

We cannot leave the Charnwood area without recording the public-spirited action of the late Mr. Charles Bennion in securing for the community Bradgate Park, the home of Lady Jane Grey, and of the Leicester Rotary Club in preserving the beautiful Swithland Woods, threatened with destruction for building purposes. Mr. Bennion's son and Messrs.

Bastard and Viccars have added to his gift. Nor can we refrain from regretting that an open area adjacent to the beautiful Swithland Woods should be spoiled by the unsightly erection of hutments for week-end visitors.

To conclude our brief account of the Leicester Region we have yet to describe Leicester itself in the Soar Valley. The river has cut out a wide flat flood plain which varies in width up to a mile. For a distance of about 12 miles the right bank of this flood plain is formed by a minor escarpment caused by the river cutting into the Rhætic limestones of the lower Lias.[2] At Barrow-on-Soar, about 6 miles north of the city, the presence of a lime works indicates the utilisation of the stone to make an excellent hydraulic cement from which drainpipes and artificial paving stones are made. This cement hardens readily under water and is therefore of great value for coastal and harbour work. The beds are of especial interest to the geologist, since in them have been found many fossil reptiles of the Jurassic period.[3]

The original site of Leicester was a gravel terrace on the east side of the river Soar. This dry terrace was the chief town or camp of a Celtic tribe. It was occupied by the Romans who carried through it the Foss Way on its way from High Cross to Lincoln. Above and below this point the river valley was marshy. The gravel terrace coming close to the water's edge doubtless formed a convenient crossing point for the Foss Way, and an equally convenient terminal point for the Via Devana, which, starting from Colchester, ran by way of Godmanchester and Medbourne to Ratæ Coritanorum, as the Romans called Leicester. The many Roman remains found in and about Leicester indicate something of the importance of Leicester at the end of this line of route to the Romans. With the departure of the Romans in the fifth century, the land approach from the south-east was replaced by the water approach from the north, along which came first the Angles and later the Danes. Both Angles and Danes have left traces of their occupation of the region in the numerous place-names terminating in 'ton,' 'ham,' and 'by.' This latter termination, of Danish origin, is very common along the rivers Soar and Wreake, then navigable streams, as at Sileby, Rearsby, Frisby, Asfordby, and Kirby.

The modern city has spread far beyond the limits of its original site on the gravel terrace by the river. Its chief expansion has been eastward up the face of the Rhætic escarpment and on to the plateau top beyond. On the plateau top is a fine open space, the Victoria Park, at the south-west edge of which, overlooking the city, are the buildings of the University College. One of the best residential areas in the city now extends along this high ground for a distance of about 2½ miles south-eastward to Oadby. This high ground carries the main road to London and forms a clearly marked plateau-like ridge running north-west and south-east. It is bounded to the north-east by the sharply cut valley of the Willow brook,

[2] This escarpment is greatly obscured in places by boulder clay.

[3] Although this lime works is still in operation, the local quarries supplying the raw material have been abandoned, owing to the increasing thickness of the clay overburden.

running to the Soar and to the south-west by the Knighton brook, another tributary of the Soar. To northward and southward along the east bank, and to a lesser extent along the west bank of the river, working-class and manufacturing areas have sprung up. Many of the older manufacturing establishments are along the river and near the centre of the city on the low ground. Newer industrial areas have developed in the tributary valley to the east and in the Belgrave area to the north. On the higher ground of the Dane Hills to west of the city a better type of residential area has recently grown up at Western Park. Near the centre of the city are grouped the chief retail shopping areas, the offices of wholesalers and of the chief professional firms, such as lawyers, accountants, architects, auctioneers, insurance agents, and the head offices of banks. Here also are the retail and wholesale markets, the municipal offices, the headquarters of the omnibus services, the Colleges of Art and Technology, and, just outside the centre, the main stations of the railways serving the city.

The retail market-place and the motor-bus headquarters are of particular interest, because they typify an increasing link between the city and the surrounding countryside. Leicester, in addition to her manufacturing activities, is a great market and distributing centre for the whole of the region we have discussed above. Markets are held three times a week in the market-place. To that held on Wednesday the country people flock both to buy in the market and in the adjacent shopping centres. The added transport facilities offered by the motor bus have tended in the last few years to increase this side of Leicester's activities. The importance of the pastoral activities of the surrounding countryside is emphasised by the size of her periodical cattle and sheep fairs.

In the foregoing paragraphs we have only been able to glance briefly at the city. No account, however brief, would be adequate without some reference to its manufacturing activities. As these are fully discussed in a later section of the survey, we will here only touch briefly on them. The two staple industries of the city are the manufacture of hosiery and boots and shoes. Coupled to these major industries are a series of others, some of which are independent and others are subsidiary. Two of these are wool-spinning and engineering. The former is the oldest of the Leicester industries. As far back as the thirteenth century, Leicester wool had established a reputation among English wools. This reputation was enhanced in the eighteenth century by Robert Bakewell, who, on his farm near Loughborough, developed the new Leicester breed of sheep, and artificially irrigated his land to improve the herbage. Wool was spun and woven in the district by hand, and from these small beginnings sprang the wool-spinning industry of the city.

Three hundred years later the hosiery industry developed out of this wool-spinning industry in a series of villages to west of the river, and especially in Leicester, Loughborough, Hinckley and Castle Donnington. With the coming of the Industrial Revolution concentration took place in the larger centres, though the industry is still carried on under factory conditions in a number of villages, chiefly to south of the Charnwood, no doubt helped by the lower county rates and the labour supply available. To-day Leicester is by far the biggest centre in the country for the manu-

facture of woollen hosiery. The headquarters of firms with a world reputation in the hosiery industry are to be found in the city.

It is difficult to say how far, if at all, the boot and shoe industry of Leicester can be related in its origin to geographical circumstances. No doubt there have always been shoemakers in the city. No doubt their work was facilitated by the skins obtained from the adjacent pasturelands and the oak bark for tanning. Oaks were numerous on the clay-covered lowlands of the Midlands. But the modern industry, which is a highly organised example of machine production involving both steam power and inventive genius, was only developed in the city during the last century. Its raw materials to-day are drawn from all over the world ; its demands on bulk coal production are small ; the value of its finished products in relation to its raw materials is high. We can say, perhaps, that Leicester, situated almost as far from the sea as any city in England can be, is not unfavourably located for the carrying on of an industry of this type, since transportation charges on its finished products and raw materials do not affect it to the extent that they do affect the heavier industries. Once established, the supply of skilled labour, the development of subsidiary industries, and the centralisation of the organisation and finance of the industry in the city would naturally tend to attract new-comers and develop established firms. These considerations apply also to the earlier established hosiery industry. To-day Leicester is the headquarters of many of the biggest firms engaged both in the manufacturing and in the distributing end of the boot and shoe industry. Many of the latter firms control numerous retail shops scattered all over the country. Like hosiery, boots and shoes are also made in many of the smaller towns and villages in the southern part of the region.

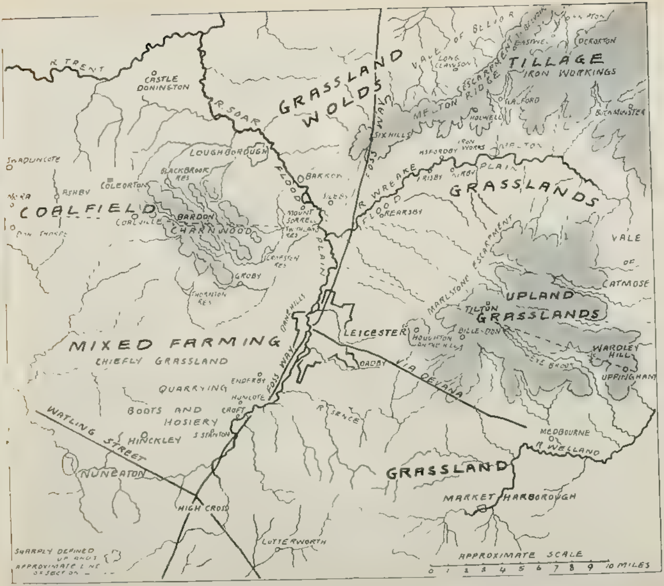
The engineering industry is in part a subsidiary of the two staple trades, and in part independent. Its chief activity is perhaps in connection with machinery for the two staple industries. In addition, it produces a great variety of other machines and appliances, particulars of which will be found in the section of this survey which deals with engineering.

Loughborough to north of Leicester is situated on the west bank of the Soar. It is primarily a local market centre. In addition to this function it has developed hosiery, engineering and bell foundry industries, and contains Loughborough College, which has attained a widespread reputation as a centre for engineering training on production.

We have already briefly touched on the roads of the region and the production of road metal. From the broader standpoint of road communication in relation to outside areas Leicester is very favourably situated. A straight line on the map from the London Docks to the Manchester region passes close to Leicester. It roughly corresponds to the main route from London to the north-west. Using either the route through the gap in the chalk near Luton or that at Dunstable, road traffic enters the Leicester region at Market Harborough. Thence, by way of the Soar valley and Leicester, it passes north-west to Derby, and from there has a choice of three routes to Manchester. Other main roads radiate north, east, south, and west to Newark, Grantham, Stamford, Peterborough, Rugby, Coventry, Birmingham, and Burton. With two exceptions these roads

keep to the valleys or the low ground. The exceptions are the Roman Foss Way, which crosses the Wold country to Newark, and the road to Peterborough, which rises over the Jurassic uplands. The Grantham road, which uses the Wreake valley to Melton, is forced to rise over the Melton Ridge. The railways mostly keep to the river valleys or the low ground, avoiding the three areas of upland, but the railway from Melton to Nottingham is forced to tunnel under the Melton Ridge, and that which runs directly eastward from Leicester towards the marlstone escarpment tunnels under a spur before turning south-east through a gap in the escarpment. Water communication is not much used, though the Soar is canalised to its junction with the Trent.

In the above rapid survey of the Leicester region we have necessarily been forced to sketch in the broad outlines and omit detail. We have seen, however, something of the more obvious relationships between man and nature in the region, and something of the way in which the cultural forms express that relationship. The position of the city, the areas of grassland and tillage and their subdivisions, are related to slope, elevation, soils, drainage and climatic conditions. The iron workings, the coal mines and the quarries are related chiefly to the geological structure; the roads and railways to the relief; the reservoirs to elevation, slope, stream and rainfall; the hikers, week-enders, and other visitors in the Charnwood to the scenic beauty of the physical setting. The focusing of much of the economic and other activities of the region on the city is mainly a matter of distance, but partly also a matter of its position in relation to a series of highly diversified neighbouring areas, and of its size as a large manufacturing entity with the many subsidiary industries and activities which that fact involves. The city is perhaps fortunate in that her two staple trades, hosiery and boots, help to supply one of the three great primary needs of mankind, the need for clothing, and that, while she carries on a large foreign trade, the main market for these goods is at home. She is also perhaps fortunate in being located in one of the richest grassland areas in England, for it is on the grassland with its production of beef and mutton, milk and cheese, under steadily improving methods of handling, that much of the future prosperity, and therefore the purchasing power, of the English countryside would seem to depend.



Sketch Map to illustrate Leicester in its Regional Setting

[To face p. 10

II.

GEOLOGY

BY

H. H. GREGORY, M.A.,

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Position of the Area—Chief Rock Formations—Charnwood Forest Rocks—Granitic Rocks—Mountsorrel Granite—Carboniferous Limestone—Millstone Grit—The Coal Measures—The Triassic Rocks—Rhætic Beds—The Lower Lias—The Middle Lias—The Marlstone Escarpment—Ironstone at Tilton—The Upper Lias—Inferior Oolite—Glacial Drift and River Deposits—The Quarrying Industry.

LEICESTERSHIRE can claim much of interest in the diversity of its general geology. Situated as it is in the Midlands of England, it forms part of the wide central plateau which is composed of Triassic and Jurassic rocks. It lies to the south of the southern termination of the Pennine axis, around which sweeps the plain of Triassic rocks on both the east and the west. Two narrower arms of this central plain bifurcate from the area and continue northwards. On the eastern margin of the Trias the Jurassic rocks form prominent scarp features. The line separating the Triassic and Jurassic rocks runs across the irregularly pentagonal-shaped county of Leicestershire from a point about two miles west of Lutterworth in a N.N.E. direction, through Dunton Bassett and Wigston, passing east of the city of Leicester to Brooksby in the Wreake Valley, thence westwards to Sileby and north-north-westerly to Stanford-on-Soar, when it continues northwards and north-eastwards into Nottinghamshire.

To the west of this line the Triassic rocks form the major portion of the solid floor of the surface of the county through which appear the older rocks, for which Leicestershire is so justly famed, while to the east of the line the lower and middle Jurassic rocks (Lias and Oolite) rise in escarpments, whose scarps, where prominent, face westwards. A variety of resulting physical features and land forms within this area is therefore not surprising.

Were the superficial deposits (glacial boulder clay, sand and gravel) to be removed, the city of Leicester would be seen to be almost centrally situated in the county, nestling as it were in the lea of the Jurassic rocks and itself built on the Keuper Marls, but within easy access of each of the outcrops of the other geological formations and in a position at the navigable head of the river Soar. The river Soar, for much of its course, actually skirts the line separating the Triassic and Jurassic rocks.

The north-eastern lobe of the area culminates in the Belvoir ridge, an escarpment composed of Lower and Middle Lias rocks, of which

the latter are largely quarried for ironstone to supply the local furnaces at Holwell, near Melton Mowbray.

The eastern margin is formed of typical ‘ wold ’ country comprising hills of circumdenudation with cappings of soft Upper Lias clay and inferior Oolite outliers culminating in Whatborough Hill, near Tilton, which reaches a height of 755 ft. above sea-level. The eastern boundary of the county descends in a general southerly direction to Great Easton in the Welland Valley and then by a south-westerly course along the river through Market Harborough to Catthorpe, near Rugby.

The county boundary then runs along Watling Street, over Triassic rocks, to the neighbourhood of Atherstone, and then north-eastwards across Coal Measures of the Ashby and South Derbyshire Coalfield, Millstone Grit and Triassic rocks to the river Trent at Long Eaton.

The oldest rocks in this area appear at the surface through the covering of Keuper Marls, about six miles north-west of Leicester and about three miles west of Loughborough on the west side of the Soar valley. These are the pre-Cambrian rocks of Charnwood Forest.

The highest point is Bardon Hill, 912 ft. high, though several commanding view-points rise to a height of over 800 ft. These include Timberwood Hill, Beacon Hill, and Birch Hill.

The Charnwood Forest sequence consists of a varied suite of pyroclastic volcanic ashes, agglomerates, grits, hornstones, conglomerates and slates, which have been divided into three conformable series. The oldest, the Blackbrook series, has not been subdivided and consists of greyish massive grits interbedded with greyish and greenish hornstones, often beautifully banded and heavily stained along the joint faces from the overlying Trias. On Ives Head occurs a porphyritic Felsite dyke unrelated to any other known rocks of the Forest.

The Maplewell series consists of tuffs, agglomerates and hornstones and comprises several subdivisions, the most striking of which the Slate Agglomerate—an andesitic tuff containing fragments of purple and green slate—is traceable on both sides of the anticline.

The Brand series, consisting of conglomerates, grits, quartzite and slates, forms the outermost beds, several of which have been formerly worked for roofing slates. This industry has now become extinct.

The Charnwood rocks are stated by Prof. W. W. Watts to be ‘ not like the Uriconian or Torridonian rocks unless we except the grits and conglomerate of the Brand series, which have some resemblance to the Torridonian rocks. On the other hand, they have nothing in common with the gneisses and schists of the north-west or central Highlands of Scotland. Many of the individual bands are like those of the Longmynd in Shropshire, and indeed if we could imagine the pyroclastic materials from the Charnwood volcano dropped far from the vent and sorted and stratified in water, they would be likely to produce a group of rocks much like those of the Longmynd. It is impossible at present to push the comparison further, and meanwhile it may be better to be content with naming the whole group the Charnian System, and to refer it to some unascertained position in the great pre-Cambrian sequence.’

The beds forming the Charnian System were folded by earth move-

ments into an ellipsoidal dome or pericline. This dome was traversed along a north-east to south-west axis by a major fault, which displaced the relative levels of the two halves so that the denuded south-eastern portion only raises its jagged crags above the mantle of Keuper Marls, while much of the remaining portion still lies buried to the north-west.

Faults and thrusts, however, have greatly dislocated large blocks of rocks, thus disturbing the general continuity of the beds around this semi-ellipse or periclinal dome. Many of the subdivisions, however, can be located so as to reconstruct the once perfect continuity of the pericline.

The movements which produced these structural features directed the intrusion of igneous rocks.

Into the pyroclastic volcanic rocks, grits and slates of the Forest several types of igneous rocks were intruded, the chief of which are quartz-diorite-porphyries, or so-called ‘porphyroids,’ and augite-syenites.

The quartz-diorite-porphyries, or so-called ‘porphyroids,’ which occur at Peldar Tor, High Sharpley, High Cademan, Grimley, High Tor Farm, Birch Hill and elsewhere were first intruded. These bear strong evidence of shearing and crushing, probably by the main north-west and south-east movements of pre-Cambrian date. These rocks only occur in the north-west portion. Lenticular-shaped masses and bosses of augite-syenite, granophyric in texture, which bear no marked evidence of shearing, and which, therefore, were of later intrusion than the ‘porphyroids,’ occur in Bradgate Park, at Groby, Markfield, Hammercliffe, Bawdon Castle, Newhurst and elsewhere in the Forest. Further afield, at Enderby, Narborough and Croft, Earl Shilton and Stoney Stanton, finer-grained igneous rocks occur, giving rise to noticeable tumulus-like hills. These latter, however, may possibly be of later age.

The main folding, faulting and cleaving of the Charnwood Forest deposits, and the intrusion into them of the igneous rocks, appear to have taken place in pre-Cambrian times. But from that date onwards until Middle Triassic times, if not somewhat later, the region was subjected to denudation. At the present time the majority of the rocks are only just being uncovered, and so, as Prof. Watts has picturesquely stated, ‘they still present a scarcely altered Triassic landscape; to this day many of the summits are as rugged and precipitous as when they were mountain tops overlooking a Triassic desert, or just submerged beneath the waters of a Triassic lake.’

In the Nuneaton district, lying to the south of Atherstone, Cambrian rocks—Stockingford Shales—traversed by numerous dykes of diorite occur. The igneous rock lies in sheets and varies greatly in thickness from 200 ft. to small veins, often following the line of strike. The Warwickshire coalfield succeeds the Cambrian shales on a synclinal trough to the south.

The only intrusion of granitic rocks exposed in the area and for a considerable distance beyond its boundaries is the Granite of Mountsorrel. Covered by a mantle of Keuper Marls, its extent beneath the cover is unknown.

Investigations of the extent of the Mountsorrel area eastwards have

afforded no positive knowledge, but the magnetic anomaly which has been known to exist in the neighbourhood of Thrussington has been again investigated, and it is probable that the granitic intrusion of Mountsorrel extends eastwards into that area under the cover of the Secondary rocks of the east side of the county. Geophysical methods have been used with some success in this research by members of H.M. Geological Survey. These methods will be demonstrated on the site during the visit of the British Association.

The area of this igneous mass lies to the east of Charnwood Forest, approximately six miles north of Leicester and to the west of the main Loughborough-Leicester road. It is prominently exposed at Castle Hill, Mountsorrel, and large quarries are located to the west and north-west in the near neighbourhood. A boss forms the fine wooded feature of Buddon Wood which overlooks the Swithland Reservoir around the margins of which are found some of the finest modifications, including hornblende-gabbro, of this interesting granitic area.

The Mountsorrel granite mass is essentially and integrally separate and distinct in age from the neighbouring Charnwood Forest area. No indisputable contact with the Charnian rocks is exposed, though, on its western margin, a hornfelsed rock with garnets is found. The Mountsorrel area shows no evidence of having been affected by the earth movements which have produced the structural complexities of the Forest. It is therefore newer than pre-Cambrian in age and may be as late as Carboniferous, though petrologically it resembles the post-Silurian granites of Britain.

Mineralogically and petrologically the rock of the main mass is a granodiorite which increases in basicity westwards. It occurs in two forms—red and grey—in the main quarry.

It is traversed by several veins and dykes of varied composition, which include aplite, dolerite, diorite-porphyrite, augite-andesite and orthophyre, though these are not of great numerical significance.

On the western edge of Swithland Reservoir is a boss of quartz-mica-diorite, of which Brazil Wood is composed, while on the opposite margin at Kinchley the contact of this rock with the Mountsorrel granite occurs. In this small exposure masses of diorite of varying coarseness occur as xenoliths in the acid granite together with veins of aplite or micro-granite. This intimate intermingling of two igneous masses is indeed striking and shows almost every gradation of mixing.

Dr. E. E. Lowe, in his monograph on the *Igneous Rocks of the Mountsorrel District*, aptly states : ' It would seem that at Kinchley we have a manifestation of invasion phenomena similar to those developed on a grand scale in Jersey, Skye, and other classic localities. Our manifestation is a very modest one, it is true, but in spite of restricted area, Kinchley possesses interesting and instructive features which make it well worth the attention of geological students.'

Recently Mr. J. H. Taylor has been working on the petrology of the Mountsorrel igneous rocks. He considers that the quartz-mica-diorite is of hybrid origin, the result of assimilation of the hornblende-gabbro by acid magma. There is evidence to show that the earliest acid magma

to be injected in the Mountsorrel area was of alkali granite type, and it is suggested that the granodiorite itself is the result of basification of this magma. Mr. Taylor has also studied the accessory minerals of the rocks in detail and records some twenty different species.

Inliers of Carboniferous Limestone occur to the north-west of Charnwood Forest at Grace Dieu, Osgathorpe, Barrow Hill, Breedon Cloud and Breedon-on-the-Hill on a fault line which is a continuation of the main Charnian axis. On a parallel line similar outcrops are brought up at Dimminsdale, Calke, and Ticknall, just beyond the border of the county. The rock is a magnesian limestone or dolomite and is now extensively worked at Breedon and Breedon Cloud. A rich fauna, which is somewhat decomposed, is found both at the Breedon quarries and at Ticknall. Limestone shales also occur in association with the Carboniferous Limestone at several of these localities.

Millstone grit occurs near Thringstone and again south-west of Ticknall, but these outcrops may belong more to Coal Measures with which they are in close proximity, and are of little significance.

By far the most important beds in the Leicester district are the Coal Measures, which are exposed at the surface over an extensive area of upwards of 70 square miles to the west and north-west of Charnwood Forest. The Coal Measures are divided into three parts, a central district of unproductive measures containing no important coal seams, and the lowest measures with an axis north-west—south-east, forming an anticlinal arch through Ashby-de-la-Zouch. On the south-west side lies the productive South Derbyshire and Moira Coalfield, separated by the Boothorpe Fault, while on the eastern flank is the Coleorton Coalfield, bounded on its eastern side by the Thringstone Fault. The Coal Measures further to the south-east are overlain by Triassic rocks, but are extensively worked as far south as Desford.

The Triassic rocks cover a greater area than any other solid formation in the Leicester district. By far the major portion consists of the Keuper Marls, often beautifully inter-banded with thin bands of sandstones and green marls as at Sileby and Enderby, while on the north-western side of the county the Keuper sandstone and also some associated beds of the next older member, the Bunter Pebble beds with sandstone beds, occur in close association with the Coal Measures and Charnian rocks.

Near Leicester beds of Gypsum occur in the Keuper Marls.

The transitional Rhætic beds occur as dark shales in the area, but the only exposure, at Glen Parva, which has yielded very rare fossil remains, is now inaccessible.

The outcrop of the Lower Lias extends from the Vale of Belvoir in a wide strip of over 4 miles to form the basal feature of a projecting spur of Liassic rocks, which reaches as far west as East Leake Hills. Its outcrop, however, is almost wholly obscured by drift deposits. At Barrow-on-Soar, the Lower Lias was until recently quarried extensively for its hydraulic limestone, which was used for the making of cement.

The Lower Lias in this area consists of a lower and an upper series of beds. The lower series comprises thin bands of argillaceous limestones, varying in thickness from about a foot to a few inches, interbedded with

blue shales. These beds of the lower series have been quarried at Barrow-on-Soar, yielding many large fossil reptilian remains of *Plesiosaurus macrocephalus* Owen, *Ichthyosaurus communis* Conybeare, *I. tenuorostris* Conybeare, as well as numerous fossil fish. Many of these specimens can be seen in the Leicester Museum and Art Gallery.

At Kilby Bridge, south of Leicester, similar beds have been worked until recently, but at both quarries work has now ceased on account of the great thickness of useless overburden of glacial drift which first had to be removed.

In the upper part of the Lower Lias, blue clays and shales of considerable thickness occur. These upper beds are only exposed along a narrow tract of country below the Middle Lias escarpment, and along the numerous small streams which flow westwards into the Soar.

In the clay pit at Glen Parva brickyard, the base of the Lias is seen resting on the Rhætic Shales.

The Middle Lias outcrop traverses the county from near Harstone on the north-east border, south-westerly through Eastwell and Holwell to Old Dalby, thence eastwards to Sproxton, southwards to Wymondham and then in an irregular outcrop through Burrough Hill, Tilton, Billesdon, Goadby and Hallaton, to the near neighbourhood of Market Harborough in the south-east. Following a series of sinuous curves, its outcrop, where free from drift, forms a marked topographical feature or escarpment, with outliers which have been denuded from the main outcrop, as at Gumley, Foxton, Stonton Wyville, and Great Bowden in the southern part of the county.

The Middle Lias comprises two important divisions,—the rock-bed consisting of Marlstone and the shales below the rock-bed.

In the north-eastern area the Middle Lias forms a prominent and unbroken escarpment, stretching from Belvoir Castle to the neighbourhood of Old Dalby. The Marlstone forms the protective capping to this escarpment whose highest point (569 ft.) is reached at Broughton Hill, near Wartnaby. Around Belvoir Castle the country is well wooded and very picturesque, the escarpment offering a number of very fine view-points in the area. The ridge itself is divided into three large outcrops by a great sheet of boulder-clay which overlaps its southern edge and extends down the scarp slope for some distance on to the Lower Lias below, forming gaps at the head of which are the villages of Eastwell and Scalford.

In the neighbourhood of Tilton, the Middle Lias attains its greatest thickness and forms a series of bold escarpment features. These bold features can be seen wherever the rock-bed is free of drift, as at Life Hill (727 ft.). Billesdon Coplow marks the most westerly outcrop of the rock-bed, and is underlain over a rather more extensive outcrop by the underlying sandy shales, and rises to an elevation of 700 ft. On account of the thinning of the rock-bed southwards the Marlstone ironstone has not been extensively worked for iron ore south of Tilton, though recently much increased activity has been apparent at Tilton on account of economic conditions enabling local iron ore to be again profitably worked.

The rock-bed of Marlstone ironstone quarried at Tilton by the

opencast system is about 12 ft., though in the railway cutting near the railway station about 18 ft. of ironstone is exposed, and is underlain by sandy shales.

Further north, around Somerby and Pickwell, the Middle Lias escarpment becomes free of drift deposits, and the rockbed or 'Transition bed,' as it has been called, is well exposed as a flat-topped hill dipping gently eastwards and presenting a bold escarpment to the west around Burrow-on-the-Hill or Burrough Hill, where it attains a height of 690 ft. It is on this flat tableland that an early Romano-British encampment was located.

Over considerable portions of this area the Marlstone has been removed for supplying the Holwell Ironworks at Asfordby, near Melton Mowbray, with raw material.

There has recently been much increased activity in quarrying the ironstone, and the average annual output in this area is over half a million tons. The content of iron varies from about 23 per cent. to 29 per cent.

Above the Middle Lias in this area and separated from the Marlstone 'Transition bed,' the upper surface of which shows some penecontemporaneous erosion, are beds of clay with nodular limestone in bands and septaria. These are succeeded by the 'paper shales' and fish and insect limestones. These beds comprise the Upper Lias in this area. They form steep banks, and in quarrying the underlying Marlstone by the open-cast system for ironstone these measures form the overburden which is removed.

The Upper Lias outcrop in the north-east is only about a mile wide, but on the borders of Rutland, into which county it passes, the width is greatly increased, and east of Tilton and Tugby it attains its greatest width of outcrop of about six miles. South of the river Welland, near Market Harborough, the outcrop again narrows to pass beyond the county boundary.

On the east side of the county, in the neighbourhood of Tilton, outliers of Inferior Oolite form the cappings of the highest hills, as at Whatborough Hill (755 ft.), Robin-a-Tiptoe (726 ft.), and Barrow Hill, near Loddington, and at Launde Wood. A larger outlier in the neighbourhood of Medbourne and Neville Holt on the north side of the river Welland is capped by Lincolnshire Limestone, the upper member of the Inferior Oolite. Further north in the neighbourhood of Waltham-on-the-Wolds, Stonesby and Croxton Park, is a faulted block of Lincolnshire Limestone, a cream-coloured oolitic limestone, detached from the main mass at Sproxton, Saltby and Croxton Kerrial. Unlike the bold features usually presented in the main mass further east, this outcrop has little effect on the relief, only forming a plateau which reaches about 570 ft. at Waltham and near Lings Hill, north-west of Croxton Park.

The Lincolnshire Limestone, which varies from a ragstone or oolite to a freestone in different localities, overlies the Northampton Sand.

In east Leicestershire the Inferior Oolite series comprises the Northampton Sand, usually rich in ironstone, passing up into brown sands, succeeded by sands and clays of a lighter colour. These beds represent the Lower Estuarine series.

In the working of the ironstones, the Lincolnshire Limestone, where suitable, is worked for its lime content in smelting. Much new activity, however, is anticipated in the neighbouring district around Corby, where these beds are to be worked more extensively.

Glacial Drift and River Deposits.

Later Secondary and Tertiary rocks are not represented in the district. The major topographical features had been determined by the end of Tertiary time. All the minor features, however, owe their origin to the presence of the glacial deposits which obscure the pre-glacial topography of large areas of the whole district. The glacial deposits are essentially diverse in character, and consist of beds of older sand and gravel and older boulder-clay with quartzose sand interbedded and succeeded by chalky boulder-clay and valley drift.

These drift deposits appear to be of two distinct ages, one containing quartzite pebbles being derived from the west and north, and the other containing chalk, lias limestone and oolite from the east. Possibly a third series, found only at lower levels in the valleys and consisting of clays and gravels, were deposited at a later date, after the existing valleys had taken their primeval form.

By far the major portion of Leicestershire is drained by the river Soar and its tributary, the Wreake. The Soar is a strike stream, having cut its valley in a sigmoid curve in Triassic marls at the foot of the Jurassic scarps. It is probable that its present course approximates to its pre-glacial course. The retreat of the ice-sheet left the country strewn with thick masses of glacial detritus which, as one vast sheet, rose gradually to the watershed and fell away gradually on either side. At Six Hills it is over 120 ft. thick, while in a recent boring for water, on the outskirts of Leicester 70 ft. of boulder-clay was proved. Through this sheet the rivers and streams have re-excavated their channels, often exposing the solid strata below. The numerous brooks draining to the Soar on its right bank, north of Leicester, flow down the scarps of the Jurassic rocks into which they have eaten their head-waters, while the Wreake has collected numerous obsequent or scarp streams and joined the Soar as a stream, running along the strike of a projecting spur of these Jurassic rocks. Other interesting examples of stream abnormalities can be seen at the Brand and at Ulverscroft Mill, on Charnwood Forest, and also at Croft in the upper reaches of the river Soar.

After the final retreat of the ice-sheet, the rivers flowed at a higher level with greatly increased volume, depositing along their courses much sorted sand and gravel, which at the present day remain as river-terraces along their banks. Teeth, tusks, and skeletal bones of extinct animals, such as the mammoth, woolly rhinoceros, reindeer, bison, and others, are found in these terraces.

These deposits yield valuable supplies of sand and gravel, and a thriving industry has grown up with the ever-increasing demand. Recently at Quorn and Barkby Holt extensive works have been opened for the working of these gravels.

The Leicestershire quarrying industry has long held a premier position

in this country. The rocks at almost every geological horizon are quarried in great quantities for some industrial purpose and used in many parts of the country; the Charnian rocks and their associated igneous rocks, as well as Mountsorrel granite for road metal, setts, building stone and slates, the coal measures for coal and fireclay, the Carboniferous limestone for lime-burning and road-dressing, the marls and clays for gypsum and brick-making, the Lower Lias Limestone for cement, the Middle Lias and Inferior Oolite ironstone and limestone for smelting, and the Quaternary sand and gravels for road-dressing and concrete.

III.

THE FLORA OF LEICESTERSHIRE

CONSIDERED BOTANICALLY, AND IN RELATION TO HUMAN ACTIVITIES

BY

A. R. HORWOOD, F.L.S.

Flora in Relation to the Geological Formations—Flora of the pre-Cambrian Rocks of Charnwood Forest—Flora of the older Limestones—Flora of the Coal Measures—Flora of the Oolites—Flora in Relation to Human Activities—Scenery and Vegetation—Local Plants of Economic Interest—Great Chalky Boulder Clay—Forestry and the Flora of the District.

Some of the Local Types of Natural Vegetation.

The flora of Leicestershire may be considered like that of any other area, characterised by the nature of the soils derived from the geological formations of the area, each soil type supporting a different type of woodland and other correlated plant community. Broadly speaking, the rocks of the whole district consist of four or five main types.

(1) *The pre-Cambrian Rocks of Charnwood Forest*, largely of volcanic origin, of higher elevation than the rest of the county, mountainous on a small scale, and affording generally sandy or siliceous soils, bear woods of oak, pedunculate and sessile, oak-birch heath, or birch wood, grass heath, siliceous grassland, calluna heath, and heather moor. Such soils being largely confined to the area of Charnwood, the plant associations named and the component species are likewise more or less confined to Charnwood Forest.

Deforested several times, Charnwood Forest was probably once part of a former more extensive forest, part of the Forest of Arden, stretching from the Avon to the Trent, and beyond to Sherwood, and eastward to Lyfield,

or Leighfield, in Rutland, and Rockingham in the north of Northamptonshire. Thus, only remnants or vestiges of original forest survive, and no very old oaks are left, the communities named being derivations from woodland. A large area has been enclosed, cultivated, drained, and materially altered artificially. The tendency, moreover, all over the open areas which have become drier, causing the moor peat to lose its character, is for bracken to overrun the district, and to oust less aggressive members of the communities named. A few illustrations with examples of a moiety of the more characteristic plants of each locality selected are all that can be attempted in so brief an analysis. Thus, at High Sharpley, on Sharpley porphyroid and Beacon beds, at 600–700 ft. O.D., there is evidence of this spoliation of more natural vegetation, heather moor, calluna heath, siliceous grassland and grass heath, which of small extent individually, are intercalated, by the dominance of bracken, which has overrun them, and eliminated other species. Here grows one of the rarest plants in the county, the cowberry, *Vaccinium Vitis-idæa*, which only extends to a few square yards. It is a northern montane plant, which here reaches its most southern limit in the Midlands. Bracken is dominant as a whole. Mat grass and purple moor grass form a belt around the lower part of the slopes, the former sometimes dominant, in drier places, the latter in wetter spots, as elsewhere on the Forest, where the peat layer has become exposed to drainage on the one side or waterlogged on the other. Old rills are filled with various rush species, bog moss (sphagnum), or Harpidia, etc. In between, hummocks are formed by *Calluna*, or ling, and *Vaccinium Myrtillus*, whortleberry. Cross-leaved heath or bell heather is scattered amongst the heather in more peaty, moister situations. Occasionally bog moss or sphagnum (where sundew also, no doubt, grew formerly) fills the surface rivulets, formed to drain the enclosure, and occupies the lower, wetter slopes. Dwarf furze, characteristic of the Forest area generally, is more frequent on the more rocky slopes or dry knolls. Wood sage, sheep's sorrel, heath hair grass, early hair grass, a montane glaucous form of annual meadow grass, buckler fern, circle round the higher ground near the rocks, with occasional patches of ling and whortleberry in crevices. Bracken is generally dominant on the drier slopes, gradually eliminating other species and obscuring the traces of the various successions following the original oak wood. There are a few small bog pools with a water buttercup (Lenormand's crowfoot), water blinks, lesser spearwort, montane hepatics, lichens, desmids, diatoms, etc. On the rocks on the north side overlooking the old Blackbrook Reservoir (now Loughborough Waterworks), where sundews, etc., once grew, rupestral montane mosses and lichens are more abundant, and in wetter spots sphagna, whilst *Empetrum* probably grew in moist ground to the north-east. Bog violet, marsh pennywort, green-ribbed sedge, heath rush, heath wood rush, pill-headed sedge are other characteristic species that form small societies here and there. Generally speaking this then is upland moorland, very different to the great grassland tracts on the clay plains of the rest of the county.

Spring Hill, Peldar Tor (700 ft. O.D.), is another area, on Peldar porphyroid, which forms a similar modified type of heather moor and

calluna heath, with whortleberry and ling forming hummocks on high ground, with heath hair grass, mat grass, and purple moor grass, etc., as at High Sharpley, gradually being dominated by bracken, and in process of elimination. Here is the only station now for the crowberry, *Empetrum nigrum*, much endangered by quarrying operations, and petty whin, *Genista anglica*, a plant which has become very rare in the county, elsewhere recently seen only at Six Hills. For the rest the characteristic species resemble those of High Sharpley, occurring in different degrees of frequency, with birch and pine here and there, becoming locally abundant, and the same applies to contiguous tracts at Charnwood Heath, just above the Hanging Stone, where formerly grew the hare's tail cotton grass, which was, no doubt, once dominant there, and probably helped along with sphagnum, to contribute to the moor peat cover of these ancient rocks. This peat layer has become so thin and desiccated that it can no longer support its characteristic vegetation—heather moor or calluna heath—and is now being further altered by the growth of bracken, calluna and whortleberry, with the absolute elimination here and everywhere else on the higher ground of North-west Charnwood, of the purple heather (not seen since 1886), which was, no doubt, as common once as ling to-day in places. Much of this ground is now calluna heath or dominated by grass types and grass heath, siliceous grassland, with here and there holly, rowan, woodsage, seedling pines, *Ulex*, mat grass, purple moor grass, etc. Timberwood Hill adjoining, now planted up with larch at 800 ft. on Felsitic agglomerate and Beacon beds, is of similar type, with, on the open moorland, whortleberry dominant, and bracken likewise here sub-dominant, and aggressively destroying the other natural vegetation, of heather moor, etc., which includes the other common species, heath rush, ling, heath bedstraw, gorse, mat grass, purple moor grass, heath hair grass, sheep's sorrel, etc. Sundew once here has gone, like most of the other rare plants recorded in 1745–47 by Dr. Richard Pulteney, as found on Charnwood. This was largely, no doubt, due to the Enclosure in 1829, when great ploughs drawn by eight horses were used to fit for cultivation an area once forest or 'waste.'

Of woodland, Copt Oak at 700 ft. O.D., on Beacon beds, is a sessile oak wood, with sessile oak, birch, holly, rowan, and alder, with various forest Rubi, and in the ground flora bracken is dominant, but there is also much whortleberry, purple moor grass, heath hair grass, bog violet, soft grass, heath bedstraw, tormentil, heath wood rush, mountain fern (becoming scarce), bluebell, foxglove, woodsorrel, etc., and in an adjoining covert, oak-birch heath, with the two birches dominant, some sessile oak, bracken, buckler ferns, ling; in swampy, peaty places, creeping forget-me-not, marsh willow-herb, hard fern, bell heather, purple moor grass, marsh pennywort, etc.

Swithland Wood, at about 300 ft. O.D., partly on Keuper Marl, surrounding the Swithland Slates, is a damp oakwood, or oak hazel, with bluebell, great wood rush, a little bracken, hazel, cow wheat, dog's mercury, ramsons, wood anemone, yellow dead nettle, primrose; and around the slate pits, on the Swithland Slates, birch is dominant, whilst amongst the slates in clefts grows navelwort (*Cotyledon Umbilicus*),

polypody fern, etc.; and around the pits, Teesdale's cress, woodsage, foxglove, etc., typical of birch and sandy oak wood, this being a composite wood on different soil types.

Buddon Wood is similarly composite, with dry or sandy oakwood types, much holly and rowan, whortleberry, etc., around the granite, and oak hazel elsewhere on Red Marl, including the only station now for club moss. On the edge of the wood is also the only locality for subterranean clover, and also spreading bell flower, *Campanula patula*, known there since 1745. One of the best types of sessile oakwood is Benscliff Wood, at 570–700 ft. O.D., on Felsitic agglomerate and Beacon beds, with whortleberry and ling, and birch around the pillars of agglomerate, which form small kopje-like rocky knolls in the wood, with bluebell, soft grass, woodsorrel, sheep's sorrel, heath bedstraw, woodsage, wood pimpernel, in wet places purple moor grass, etc. Pine, beech, and wych elm have been planted.

(2) The next distinct type of rock includes the *older limestones*, or Carboniferous Limestone of Breedon, Breedon Cloud (the wood itself partly also on Red Marl, and Boulder Clay, or ash oak, with yellow star-of-Bethlehem, Solomon's seal, butterfly orchid, giant bellflower, hybrid cowslip—primrose, often called 'oxlip,' etc.), Barrow Hill, Osgathorpe, Gracedieu. This is not a pure limestone, but an earthy magnesian limestone of a creamy-buff colour, not blue like the typical limestone at Calke and Ticknall, just over the Derby border.

At Breedon Hill old quarry, on the limestone grassland formed on it at 380 ft. O.D., a typical limestone flora is developed, including musk thistle, mountain flax, lady's bedstraw, wild thyme, mullein, sheep's fescue, Kœleria, white bryony, stork's bill, cudweed, biting stonecrop, wild parsley, white campion, rue-leaved saxifrage (growing on the rocks), wall rue fern, Burnet saxifrage, musk mallow, perforate St. John's wort, harebell, etc.; and on similar rocks at Barrow Hill (280 ft. O.D.), oxtongue, marjoram, wood reed grass, creeping rest-harrow, barren strawberry, quaking grass, etc.

(3) On the third type of soil, sandy as a whole, in the *Coal-Measure area*, around Ashby-de-la-Zouch, the woods such as South Wood, Lount Wood, Ashby Old Parks, Spring Wood, Coleorton, The Smoile, etc., are of the sandy oakwood type, with pedunculate oak, hazel, bluebell, soft grass, woodsage, foxglove, common speedwell, rosebay, woodsorrel, etc., and in peaty pools, common loosestrife, wood reed grass, tussock sedge, creeping forget-me-not, *Carex Pseudocyperus*, etc.

One of the most interesting areas in the county is on the peat and alluvium formed on Coal Measures at Moira Reservoir, there being aquatic and marsh formation, alder willow and fen carr, oak-birch heath, and formerly calluna heath to the west, where purple heather, ling, etc., grew. The very rare *Tofieldia palustris* was found here in 1820 by Dr. J. Moore, and was a relic of the Arctic and montane flora which extended south in the Glacial period, and on retreat of the ice was only able to persist at the higher altitudes formed by the Pennine Chain, of which Charnwood Forest and its adjacent north-west area is a prolongation. This is also the only locality for the pillwort, and the sole station for

marsh cinquefoil, shoreweed being likewise abundant in the Reservoir itself. Several rare Rubi also grow here, and in the district, and although now styled a reservoir this, once feeder of the old Ashby Canal, was doubtless a natural pool in the wildest surroundings, before it was completely transformed by coal-mining operations. The canal itself contains *Elisma natans*, and on its banks *Sagina nodosa*, etc.

Groby Pool, which is in the south-east corner of Charnwood, in a hollow of Red Marl and Granite surrounded, at ' Frog Hole,' with a cover of peat and alluvium, at about 300 ft. O.D., is another old natural reservoir, where there is quite a large assemblage of rare plants. In the pool itself mare's tail, bladderwort, and recently a gentianaceous water plant, *Limnanthemum*, have been found. In the marshy alder swamp at the back grow grass-of-Parnassus, bog bean, marsh helleborine, and other marsh and spotted orchids, twayblade, marsh pennywort, two kinds of cotton grass (not the hare's tail, once erroneously reported), marsh bedstraw, marsh red-rattle, great and lesser spearworts, bog speedwell, various water buttercups, a great variety of sedges, some rare, marsh spike rush, etc., besides all the more usual marsh and aquatic plants. By the roadside hardby occur, in grass heath, silver cinquefoil, soft knotted clover, hare's-foot trefoil, red sandwort ; in the quarry clammy groundsel, American cress ; and in the adjoining Sheet Hedges or Groby Wood, a sandy oakwood in part, both golden saxifrages, bear's garlic, columbine, foxglove, cow wheat, pretty St. John's wort, giant bellflower, hawkweeds, etc.

(4) *The newer Limestones or Oolites* constitute a fourth type, the Lincolnshire Limestone, forming calcareous soils and limestone pasture. On the Cotswolds and elsewhere the beech and ash form woodland, but locally in north-east Leicestershire around Saltby where this type is best developed there is very little woodland. Limestone pasture occurs extensively at Saltby, Stonesby, Sproxton, Waltham, on the Mere Road, and elsewhere. This flora includes the typical grasses, tor grass, as aggressive as bracken, and tending to destroy or exclude the more interesting members of the association, especially in Rutland where limestone pasture is better developed, erect brome grass, sheep's fescue, Kœleria, rock rose, horseshoe vetch, purple milk vetch, marjoram, autumnal gentian, field gentian, lady's fingers, pyramidal orchid, bee orchid (also on older limestones at Breedon Cloud Quarry and elsewhere on Lias, etc.), early spotted orchid ; long-stalked crane's bill, yellow wort, dropwort, greater knapweed, and the rare chalk milkwort at Sproxton (also in Rutland where I found it six weeks earlier on April 28), squinancy wort, white mullein (King Ludd's encampments), field ragwort ; and formerly pasque flower and mountain everlasting were said to grow near here. At Saltby also is an interesting limestone swamp at the junction of the Upper Lias and Northampton Sand, with several plants previously confined to Charnwood Forest, and thought to be extinct, viz : butterwort, black bog rush, etc. Besides these there may be found in this north-east area many other limestone plants of more general occurrence. In the Harston district also the Marlstone supports a distinctive limestone flora, and the Upper Lias a series of woods resembling sandy oak woods, with

Digitalis, *Pteris*, etc., and at its junction is a limestone swamp, with Sphagnum (very rare outside Charnwood Forest), mountain fern, heath rush, and several other interesting helophytes.

(5) In East Leicestershire a series of woods of ash oakwood type occurs on the Great Chalky Boulder Clay, Middle and Upper Lias clays and loams and calcareous sandstones and marls, with a characteristic flora not found elsewhere, including wood forget-me-not, which colours the woods a cambridge blue in May and June ; nettle-leaved bellflower, lesser teasel, herb Paris, wood vetch, small reed grass, etc.

The Flora of Leicestershire in relation to Human Activities.

Leicestershire as a great grassland country.—As ' the Shires ' Leicestershire is a great grassland county which affords some of the best hunting in England, fox hunting having been a recognised occupation as well as pastime locally since about 1670, when a pack was kept at Tooley Hall, near Peckleton. This excellence of grassland is no doubt due to the prevalence of a clayey or clayey loam soil over a wide area. It is in fact especially characteristic of the clays and loams of the Lower Lias, Upper Lias, and Great Chalky Boulder Clay, and other less extensive outcrops, e.g. Middle Lias. On these clays the grassland appears to be especially suitable for cheese-making. Stilton cheese which goes all over the world was first made at Withcote, but sold for a family reason as Stilton. Withcote is in East Leicestershire on these clays. It was the originator of the old Board of Agriculture, William Marshall, who, in 1790, in his *Rural Economy of the Midland Counties*, one of his agricultural surveys of every county, first showed the necessity for studying the character of the grassland in order to select the best land for cheese-making. For this purpose, during his survey of Leicestershire, he made careful lists of all the species of grasses, legumes, and other types in each field, noting the frequency of each species. He likewise cultivated grasses to determine which was more suitable for this purpose. Marshall was thus really the first ecologist in this country, not only in recognising the difference between different grass types on different soils and the need for determining their dominance or frequency, but he also knew that besides the existence of different natural types of grassland, woodlands were similarly dependent upon soil ; and that there were different types of woods, based on this factor. He likewise understood that there were natural woods and artificial woods, and realised that woods on ' ridge and furrow ' were of the latter type. By cultivation of the grasses he established one of the leading principles of modern plant breeding and genetics.

Scenery and Vegetation : the Beauty of Charnwood Forest.

Natural vegetation is based mainly upon the geological formation and soils to which they give rise so that where the one is diverse the other will be equally diversified. Charnwood Forest is structurally an ancient mountain chain, with its highest peaks buried and a very small proportion of its height and extent is visible. The highest point is but 912 ft. (Bardon Hill), and apart from that the rest of the high ground in the north-west is about 800 ft., whilst the general altitude of the country west of the

Forest is about 500 ft., so that the hills form but a miniature range. The high ground is pierced at short intervals by ragged sharp crags, with shallow undulations between, with occasionally steeper slopes or cliffs, as at Bardon. Sometimes the rocks are pillar-like as the Hanging Stone near Flat Hill, and Charnwood Heath, or at Woodhouse, or the Altar stones, Benscliff Wood, etc., where the rocks appear as natural altar stones or menhirs. This contrast of rock and bracken, furze, or ling-covered slopes or heights is also varied by the large number of small tracts of woodland dotted here and there, like the relics of scattered forest-land they really represent. There is thus a great diversity of physiognomic detail which makes Charnwood Forest a fascinating and picturesque region of primeval rocks and miniature moors, knoll-covered, with pine, larch, and oak, mountainous, diversified, wild. It is, as it were, a rocky islet in a sea of grass, the surrounding plains of grassland being flat or little undulating, until the great Jurassic escarpment running across Leicestershire north-east by south-west is reached. This runs north-east to Belvoir, with a break between Tilton and Burrough, and east of that line is broken up and cut into a series of meandering valleys or gorges, with striking, flat-topped hills here and there as at Life Hill, Billesdon Coplow (720 ft.), Burrough, Robin-a-Tiptoes, Whadborough, etc. This East Leicestershire country is also well wooded in places, and with its great tabular, high-level plateaux (700 ft.) and undulating dells or denes cut by the rivers Chater, Gwash and Eye, etc., it is a region of great picturesque and arresting natural beauty, seen at its best perhaps just over the Rutland border at Wardley Hill, Bushy Dales, Deep Dene—all in the Uppingham district.

Some Local Plants of Economic Interest.

In every district some local industry or craft may be found to have played an important part formerly, if not to-day. Though there is little to guide us, doubtless woad-growing and dyeing had its share in the prosperity of the Leicester community, as it did on the Continent from the Middle Ages until indigo killed the trade. Blith in 1653 spoke of the county as suitable for its cultivation, and the 'Records of the Borough of Leicester' contain fines for infringement of the strict woad regulations locally. Flax and hemp were cultivated as part of the native raw produce for the manufacture of textiles, for which woad served as a dye substance. In certain old terriers, e.g. one of Claybrooke, 1708, these crops were rendered also as part of the tithe. Old, dry hollows in the Sheepy district and elsewhere, unless marl pits, may have been retting pools where flax fibre was prepared by fermentation (there is a flax pool near Castle Donington). Hemp occurs here and there as an alien plant, perhaps as a relic, in the same way as wood and flax, of former cultivation.

Many plants figure in the former use of 'simples,' or household herbal remedies, and to this cause we may probably attribute the occurrence in almost every village of such plants as greater celandine, black horehound, marsh mallow, Good King Henry, etc., and less frequently white horehound, clary, hemlock, vervain, etc. To-day men may be seen to go round the county in autumn picking mountain or purging flax by the

sackful. Railway goods guards, I found when resident in Leicester, are particularly fond of collecting herbs on their journeys, and in this way I have secured further evidence of the occurrence of such plants as belladonna or henbane, in spots where they were undoubtedly alien. In Rutland the former is perhaps native in some woods, and great quantities were collected during the Great War for pharmaceutical purposes from Exton Park, where it is abundant.

Wild fruits of the countryside in some districts figure in season in the local market periodically, and Pulteney in 1746–1765 records the local names of the raspberry and of whortleberry brought into Loughborough or Leicester markets.

Willows of every type, sallows, osiers, etc., play a part also locally in industry, the Ellmore factory with its osier plantations at Thurmaston and elsewhere being well known. Mr. Ellmore expressed the belief that there were no hybrid willows, but Linton at Shipley, was able by cultivation and experiment to show that there were.

The Chalky Boulder Clay Area and its Early Colonisation by the Anglo-Saxons.

In Essex it has been found by Woolridge that the distribution of the Great Chalky Boulder Clay coincides very remarkably with the distribution of the Anglo-Saxon settlements and to a less degree the later Danish ones. The reason given for this is the suitability of the soil, a stony loam or calcareous marl, for crop cultivation, and the fact that it is also one of the best superficial water-bearing strata. An examination of the area of the Great Chalky Boulder Clay, largely confined to that part of Leicestershire east of the Soar valley, leads to the same conclusion, that it is more or less that area in which the Anglo-Saxons in their first settlements in the county took up their abode. That area is, moreover, almost entirely ' ridge and furrow,' a relic of Saxon drainage.

Forestry and the Flora of the District.

It is reasonable to suppose, since pine occurs in deposits of pre-Glacial age in the Midlands, that this was one of the forest trees at higher altitudes in this area, and that Charnwood Forest was once partly pinewood, which would account for the prevalence (formerly more marked) of ling and other heaths, which follow in natural succession after loss of pinewood in an area, just as bracken follows oakwood—a process in widespread operation on Charnwood at the present time. In this region the area most generally afforested was Charnwood Forest. The Domesday Survey shows large gaps between scattered woodlands, elsewhere than on Charnwood, in 1086, and the existence of much land in such areas under plough or grass as early as that period.

Charnwood Forest itself appears—if Burton be correct (though Throsby doubted him)—to have been disafforested shortly after the Conquest, and afforested by Henry II, but disafforested by Henry III. It was also bare of forest, ' almost without a tree,' in Marshall's time (1790). In recent years, since the Enclosure (1829), much pine, larch, beech, wych

elm, have been planted. It is thus almost impossible to indicate any single spot on it that could be called virgin forest, so greatly has it suffered at the hands of the woodman and his axe in the long distant past.

Note.—The Flora of Leicestershire and Rutland, by *A. R. Horwood* and *the late 3rd Earl of Gainsborough*, will be published by the *Oxford University Press* before the Leicester Meeting of the Association. *Price* £1 15*s*. With 2 maps, portraits, and botanical photographs.

IV.

THE ZOOLOGY OF LEICESTERSHIRE

BY

E. E. LOWE, B.Sc., Ph.D. (Director, Leicester Museum and Art Gallery), W. E. MAYES, R. WAGSTAFFE, and S. O. TAYLOR.

General—Published accounts—Mammals—Birds—Reptiles and Batrachia—Fishes—Freshwater Invertebrate Fauna—Protozoa—Porifera and Cœlenterata — Platyhelminthes — Rotifera — Annelida — Crustacea — Insecta — Coleoptera—Diptera—Hymenoptera Aculeata.

Leicestershire possesses no geological or geographical features so remarkable and extensive as to produce a striking or peculiar fauna. Charnwood Forest is, of course, from a geological point of view unique, and is the home of several interesting species of insects (Coleoptera) which are apparently survivals from earlier conditions, but the area of the forest is now so restricted and so cut up that it offers no other faunal peculiarities. It is a matter for congratulation, however, that in Bradgate Park, on the south-eastern edge of the forest, an area of about nine hundred acres presented to the city and county by the late Mr. Charles Bennion in 1928, certain portions have been reserved from public use and will no doubt in time produce interesting records.

There are two available accounts of the Leicestershire fauna : (1) that published in the *Victoria County History : Leicestershire*, in 1907 ; and (2) that compiled by Mr. A. R. Horwood for the handbook *Leicester and Neighbourhood*, issued to the members of the British Association on its first visit to Leicester in the same year. Both are admittedly very incomplete except in regard to such familiar groups as the birds, butterflies, moths and beetles. Many additional records have been made since the publication of these accounts, chiefly by members of the Leicester Museum staff and by workers in the ranks of the Leicester Literary and Philosophical Society, and some of these records are mentioned below. The brief notes on various groups which follow have been kindly contributed by Mr. W. E. Mayes (Mammals, Birds, Reptiles, Batrachia and Fish), Mr. R. Wagstaffe (Freshwater Invertebrates), and Mr. S. O. Taylor (Coleoptera).

Mammals.

The red deer and the fallow deer are still preserved in a semi-domesticated state in Bradgate Park and other parks in Leicestershire, but by reason of the breaking up of some of these old estates the herds have become more or less restricted. The red deer in Bradgate Park are believed to be the descendants of the ancient herd.

The badger is still fairly common throughout the county, particularly on the eastern side. The otter, on the other hand, is a much-persecuted species and is rapidly decreasing in numbers.

Leicestershire, with its vast acreage of grassland, provides the best fox-hunting in England, and it is solely due to the protection afforded to the fox for purposes of the chase that this beautiful mammal is still plentiful.

The pine marten (*Mustela martes* L.) and the polecat (*M. putorius*) have long ceased to exist in any part of the county. The last recorded appearance of the pine marten was at Bradgate in 1868. Of the small Carnivores, the stoat and weasel are still well represented, though the latter is by no means as common as the former.

In spite of the persistent war that has been waged against the mole by professional mole-catchers, for the sake of its fur, there seems to be no decrease in the numbers and general distribution of this mammal.

Though all three species of shrew are found in Leicestershire, the water shrew (*Sorex fodiens*) must be regarded as very rare. This interesting little mammal has been particularly searched for, and only two have been recorded during the past fifteen years. Both were noted during the prolonged drought experienced in the summer of 1930. It therefore seems reasonable to suggest that normally the brooks and streams of Leicestershire carry too much water to enable the water shrew to become established.

The lesser or pygmy shrew (*Sorex minutus* L.) has never hitherto been mentioned in any previous record of the fauna of Leicestershire, but in 1925 an example was found at Barkby Thorpe. Subsequent investigation has produced four more examples from other localities, proving the pygmy shrew to be an established species. That it has long existed in the county but has been overlooked is almost certain.

The common shrew (*S. vulgaris* L.) is plentiful in all parts.

Of the fifteen species of bats listed as British, only seven have so far been recorded for Leicestershire. These are as follows: Barbastelle Bat (*S. barbastellus*), Long-eared Bat (*P. auritus*), Whiskered Bat (*V. mystacinus*), Daubenton's Bat (*V. daubentoni*), Natterer's Bat (*V. nattereri*), Common Bat (*V. pipistrellus*), and Noctule Bat (*V. noctula*).

The red squirrel is not so frequently met with as formerly. Several examples of the grey squirrel have been seen or shot, but so far their numbers have not given cause for alarm.

The dormouse (*M. avellanarius* L.) and the harvest mouse (*M. minutus*) seem to have disappeared from the county. The former was doubtfully recorded previous to 1885, but there seems indisputable evidence that the harvest mouse was fairly common in the neighbourhood up to 1889.

Since that time there has been no record of either of these interesting little creatures having been seen.

The brown rat (*Mus decumanus*) is unfortunately too abundant, but no recent occurrence of the black rat (*M. rattus*) has been noted. So far there is no evidence that the musk rat, which is doing so much damage in Shropshire and other counties, has invaded Leicestershire, though recent reports state that it has been seen in Rutland.

Birds.

Since the publication of the list of birds in the *Victoria County History* of Leicestershire and Rutland in 1907, a number of additional species have been recorded. It is also pleasing to note that several of the rarer species in the earlier lists are still occasionally met with. For example, a raven was seen at Wanlip during the winter of 1919, and remained in the district unmolested for some days. Ravens nested in different parts of Charnwood Forest in earlier days, the last record of a nest being at Garendon in 1825.

A rough-legged buzzard was observed at Bradgate in 1909, and an osprey in the same locality in the autumn of 1913. Two hen harriers were seen and unfortunately shot at Normanton in 1919.

Though recorded as an uncommon summer visitant, the hobby has, for the last two or three years, nested at Barkby Holt and at Humberstone.

There are several large sheets of water around Leicester, forming part of the city's water supply. These reservoirs, of which Swithland Reservoir is the largest, have thickly vegetated margins, and form excellent habitations for most of the commoner species of water-fowl. The stately great crested grebe visits these waters every spring to nest, with a population per reservoir ranging from two to eight pairs. A very few occurrences of the sclavonian grebe (*C. auritus*), the red-necked grebe (*C. griseigena*) and the eared grebe (*C. nigricollis*) have also been recorded. The rare wood sandpiper (*T. glareola* L.) occurred at Swithland Reservoir in the autumn of 1919. The reservoirs also provide excellent feeding-places for herons. Leicestershire can boast of but one small heronry, at Stapleford Park, the seat of the Hon. John Gretton, J.P., M.P. Stapleford is situated on the extreme eastern edge of the county, and the herons are very strictly preserved. Early records show that herons have made unsuccessful attempts to establish heronries at Mere Hill, Martinshaw Wood, Buddon Wood and Bradgate.

The lapwing or green plover (*V. vanellus*) inhabits the low-lying pastures in the valley of the river Soar in large numbers.

At Wanlip is a large extent of marshy land near the river, which is used for the cultivation of osiers. The bird population of this ' osier holt ' is extensive, and several pairs of reed warblers (*A. streperus*) nest there every year. The grasshopper warbler's prolonged ' reeling ' notes may also be heard there almost every spring. In 1931 this interesting little visitor nested near the village of Queniborough.

There appears to be a marked increase in the numbers of the tawny owl of recent years, whilst the barn owl becomes correspondingly scarce. The little owl is now all too common, though in 1907 it was a rarity.

The nightjar visits the county each year, and nests are frequently found at Bradgate Park, The Brand, and other parts of Charnwood Forest.

The nightingale is by no means a rare visitant, and reports of its singing are annually received from many parts of the county.

Among records of casual visitors the following are worth noting: the black-throated diver (*C. arcticus*) at Blackbrook Reservoir in 1919; the peregrine falcon at Barkby Thorpe, 1930 and 1931; the spotted crake (*Rallus porzana* L.) at Wanlip, 1919; the black redstart (*Ruticilla tithys* L.) at Thurmaston, 1925; the dipper at Bradgate Park, 1913 (the dipper was formerly resident there).

Reptiles and Batrachia.

The common grass-snake (*T. natrix*) is still fairly frequent all over the county, whilst the viper or adder (*V. berus*) and the common lizard (*L. vivipara*), though not common, are occasionally met with, chiefly in the Charnwood Forest area. No occurrence of the sand lizard (*L. agilis*) seems to have been recorded to support Harley's supposition that this species existed in the county.

The blind-worm (*A. fragilis*) is still to be found, though it is not so common as formerly.

The common frog and the toad are widely distributed, but the natterjack (*B. calamita*) has never occurred in the county. The great crested and the smooth newt are common, and the palmated newt is believed to occur, though there is no reliable record.

Fishes.

According to early records the brook trout (*S. trutta*) was fairly plentiful in many of the smaller streams. Its present status is entirely dependent upon private enterprise in regard to re-stocking. Some of the large reservoirs, including Thornton and Cropston, contain trout, but owing to the enormous number of perch which have by some means been introduced into these waters, they are only maintained with great difficulty. Leicestershire waters have produced some very large perch. It is recorded in the *Victoria County History* of Leicester and Rutland, 1907, that in 1888 two specimens taken from Thornton Reservoir weighed 9 lb. together. The pike, too, is particularly abundant, and very large specimens have been recorded from time to time.

The common carp (*C. carpio*) is to be found in many pools throughout the county, whilst the crucian carp (*C. carassius*) is sparingly distributed.

The barbel (*B. vulgaris*) is practically unknown in Leicestershire waters, though one or two examples have been taken by anglers at the confluence of the rivers Soar and Trent. The gudgeon, roach, chub and dace are all very widely distributed, but the rudd is very rarely met with. The bleak, once very common, is now rarely seen. The common bream (*A. brama*) and the white bream (*A. blicca*) both occur in the river Soar, though sparingly of late years. The species last named is common in some of the larger pools in the county, including Groby Pool and Moira Reservoir. The stone loach (*N. barbatulus*) and the spined loach (*C. tænia*) have both been recorded. The former species is still to be found in the

small streams in Charnwood Forest. The ruffe (*A. cernua*) and the 'bullhead' (*C. gobio*) occur in parts of the river Soar. The three-spined stickleback (*G. aculeatus*), which at one time infested almost every brook and pool, is now not nearly so common. The minnow (*L. phoxinus*) is abundant in nearly all the brooks. The common eel is to be found in most waters in the county. Early records state that the lamprey (*P. fluviatilis*) was very occasionally seen, but there is no evidence of this interesting species having occurred during recent years.

The Freshwater Invertebrate Fauna.

Leicestershire with its large reservoirs of Thornton, Saddington, Swithland, Moira, etc., together with its innumerable ponds and ditches, presents ample facilities for investigation to the student of the freshwater fauna, and there is scope for an immense amount of intensive study.

Protozoa.—Many well-known forms have a wide distribution in the county. *Actinophrys sol* is to be met with in most suitable localities, while *Actinosphærium eichornii* is rather more local. Of late years the wider distribution of *Volvox globator* has become noticeable, and it is now found in places where it was formerly considered to be rare. *Vorticella chlorostigma* and *V. globularia*, although previously unrecorded, are frequent in the river Soar, the former on *Myriophyllum* and the latter on *Cyclops*. Other species hitherto overlooked or unrecorded are *Ophrydium versatile*, *Stichotricha secunda*, *Chilomonas paramecium* and *Phacus longicaudatus*.

Porifera and Cœlenterata.—There are two freshwater species to be found in the county—*Ephydatia* (*Spongilla*) *fluviatilis* and *Spongilla lacustris*. The former is to be found frequently in the river Trent and river Soar, and the latter, previously recorded only for Saddington Reservoir, is to be found also in the canal at Great Glen.

Hydra vulgaris, *H. fusca* and *H. viridis* are common. It is a surprising fact that, although of frequent occurrence, *Hydra viridis* has never previously been recorded.

Platyhelminthes.—Little attention has been paid to this group. It is noteworthy, however, that epidemics of *Fasciola hepatica* (the flat-worm which causes 'liver-rot' in sheep) have considerably decreased owing to better drainage of land and modern methods of treatment of infected animals.

Rotifera.—Almost all stretches of water are profitable hunting grounds for the members of this group. The ponds and ditches near Desford have proved particularly good, such interesting species as *Rotifer neptunis*, *Scaridium longicaudum*, and also *Polyarthra platyptera* being found in abundance at certain times of the year. In the withy pickle-dykes at Wanlip osier-beds are to be found *Melicerta ringens*, *Stephanoceros eichornii* and *Floscularia campanulata*, while *Floscularia cornuta*, *F. ornata* and *Limnias ceratophylli* are not rare in various parts of the county. Perhaps the most widely distributed forms to be found in Leicestershire are *Proales werneckii*, *Rotifer vulgaris* and certain species of *Brachionus*.

Annelida.—It is impossible at present to estimate how many different truly aquatic species occur within the limits of the county; that additions will be made to the already published list there can be no doubt, for

Leicestershire abounds in suitable localities awaiting systematic exploration. Here it is only possible to remark upon the present-day distribution of a few interesting species. *Nais proboscidea* and *Tubifex rivulorum* are common in most places ; in fact, examples of the former can be obtained from any ditch or pond in the county, while the latter is especially abundant in the reservoirs. *Piscicola geometra* occurs in many places, together with allied species, and is often introduced with fish into the Museum aquaria. In the lists given in *A Guide to Leicester and District*, 1907, the medicinal leech (*Hirudo medicinalis*) is mentioned as having occurred within the county ; unfortunately, neither date nor place of capture is stated, but in all probability it is extinct in Leicestershire as elsewhere in England, if indeed it ever occurred, for the fact that the horse leech (*Hæmopis*) occurs but is not recorded rather suggests erroneous determination.

Crustacea.—Of the five species of *Daphnia* recorded, *D. pulex* is the most widely distributed. In the canal at Great Glen, *Ceriodaphnia reticulata* is common, while *Scapholeberis mucronata* is not rare in some parts of the county. *Bosmina longirostris* is not uncommon, but the most abundant Entomostracan seems to be *Chydorus sphæricus*. Two species of *Cypris* have been taken, *Cypris fuscata* and *C. virens*. *Limnocythere monstrifica* has occurred at Fleckney.

Some seventeen Copepoda have been taken in the county, but no doubt, when more attention has been paid to the group, the number of species recorded will be increased. Two species of *Diaptomus*, *D. castor* and *D. gracilis*, the former more frequent than the latter ; ten species of *Cyclops* and five species of *Canthocamptus*, constitute the present list.

Argulus foliaceus is abundant in all the reservoirs. *A. coregoni* has been recorded for Leicestershire as the first British-taken example of this species, but as there is some doubt as to its authenticity, this record is unreliable.

That the freshwater crayfish exists in the river Soar at Aylestone has long been known. Recently it has been taken in large numbers in an artificial pond fed by a small stream at Desford.

Insecta.

Coleoptera.—The Coleoptera of the county have been carefully worked by several well-known collectors in the past, amongst them Matthews, Plant, Harris, the brothers Bates, Bouskell and others. The number of species recorded by them is more than 1,700 : quite a good proportion of the British list. Many of these records depend on the capture of single specimens which have not been taken since. The most noteworthy of them was the first British record of *Tropideres sepicola* from Buddon Wood, but it has not been seen again. The rare weevil *Trachodes hispidus*, which used to be sent all over the country to collectors, is still to be found at Buddon. An old record of one specimen of the large water beetle, *Hydrophilus piceus*, from Syston has been confirmed recently by the capture of two more from the same neighbourhood. The higher ground of the Charnwood Forest, although the highest point is little more than 900 feet, has produced a number of mountain species, and the beetles generally bear a striking resemblance to those found in North Wales.

Some of the later additions to the county list are the first British record of the longicorn (*Tetropium Gabrieli*) from Sutton Ambion, since occurring at Bardon and on the other side of the county at Keyham ; *Gnorimus nobilis*, from Loughborough, said at one time to be extinct in this country ; *Cœnopsis fissirostris*, Bradgate Park ; *Trachys troglodytes*, Owston Wood ; *Aleochara brunneipennis*, Sutton-in-the-Elms ; *Clytus mysticus*, var. *hieroglyphicus*, Wistow ; and *Cartodere filum*, Leicester. *Bembidion obliquum* and a few other species, said not to be found in the Midlands, are common near the reservoirs.

In the Museum collection of Coleoptera all the local specimens are marked with red discs, and the records, where there is no local specimen, are indicated by red discs on pins.

Diptera.—The most remarkable recent record is of a Dipteron new not only to the county but to the British Isles—namely, *Argyramœba* (*Anthrax*) *anthrax* Schranck, first taken by Mr. P. A. H. Muschamp at Woodhouse Eaves in 1929. This specimen was presented to the British Museum. In 1930 Mr. Muschamp took a second specimen at Cocklow Quarry, which is now in the Leicester Museum collection. It is difficult to understand how so distinct and striking an insect could have escaped observation had it been long in this country, and the inference is that it is probably a recent importation.

Hymenoptera Aculeata.—It is evident from the brevity of the list of *Hymenoptera Aculeata* published in the *Victoria County History* of Leicestershire in 1907 that these insects had not up to that date been seriously studied or collected in the county. Only 65 species are enumerated out of more than 350 species then known to inhabit Britain. Many additional species have since been caught in the county, but there is room for much more work, particularly in the direction of investigating habits and life-histories.

In the absence of sandy tracts of country, the old mud-walls (now, alas ! fast disappearing) supply favourite nesting sites for many burrowing species, and others find a congenial habitat in the waste heaps from quarries, when the heaps have been for years undisturbed—as in some parts of the Mountsorrel area.

This is not the place to enumerate the additions to the Leicester list, and only two will be mentioned as typical of many. One is an interesting new local record among the fossorial forms, namely *Agenia variegata* Linn., a small black digging-wasp which provisions its nest with spiders. Each spider is paralysed by a sting in one or more of the nerve centres, and so keeps alive and fresh until devoured by the larva of the digger-wasp. The first specimen was taken on the top of one of the characteristic dry stone walls of Charnwood Forest near to Stoneywell Cottage, in the act of dragging a benumbed spider to its burrow. Others have been taken since in various parts of the forest, so it is probably not uncommon, though previously overlooked.

Among the Anthophila perhaps the most interesting new record is *Anthidium manicatum* Linn. This bee has been regularly observed for several years flying at the downy *Stachys lanata* in a garden on the outskirts of Leicester, in June and July. It appears to visit nothing else. The females visit the flowers for the purpose of collecting nectar and

pollen, while the males appear to visit the plants only in search of the females. The flight of this bee is swift, and it hovers like a humming-bird before the flowers. Oswald Latter says that its nest is like a ball of white wool, and Gilbert White states that it visits the garden campion for the sake of its tomentum. It was suspected to be frequenting *Stachys lanata* for the sake of the tomentum, but, though watched carefully many times, the bee was never detected in the act of gathering or carrying the down. Nor has a nest been found. The connection between *Stachys lanata* and *Anthidium manicatum* seems close. In early July 1931 a large patch of the plant was noticed in a garden near Oxford. On going up to the patch, *Anthidium* was seen flying in numbers before the flowers. Any entomologist in the neighbourhood of Leicester could attract *Anthidium manicatum* by planting a good patch of *Stachys lanata*. It is much to be desired that local students should take up the investigation of the many biological problems which the *Hymenoptera Aculeata* present.

The information given in the foregoing brief notes on the Leicestershire fauna is necessarily somewhat disconnected and very incomplete. Members of the British Association who desire further information, however, are cordially invited to consult the members of the staff of the Leicester Museum, who will be pleased to help as far as lies in their power. They would also put visiting members in touch with local workers.

V.

THE CLIMATE OF LEICESTERSHIRE

BY

E. G. BILHAM, B.Sc., D.I.C.

General Conditions—Records kept—Rainfall—Temperature—Humidity—Wind Direction—Sunshine—Hail—Thunder—Frost.

FROM the climatic point of view Leicestershire may be regarded as typifying the 'inland' conditions of Great Britain, uncomplicated by large masses of high-lying land. A line drawn westward from Lowestoft and a line drawn northward from the Isle of Wight intersect within the county, which thus lies, as nearly as may be, in the centre of England. We should expect the climate of Leicestershire, therefore, to exemplify almost the highest degree of 'continentality' possible in a land mass of the size and geographical situation of Great Britain. That is to say, we should expect a large diurnal and annual range of temperature, a high frequency of ground frosts and radiation fogs, and a well-marked development of diurnal convective phenomena.

Unfortunately the county has never been very well served in regard to climatological observations, and we are obliged to rely, except in respect to rainfall, very largely on the records from Belvoir Castle, which is very near to the north-eastern boundary of the county. In recent years we have records from Lutterworth, kept by Mr. M. W. Binns, whose kindness in supplying data I am glad to acknowledge. At the moment of preparing these notes I have also learnt of a long record kept at Woodhouse Eaves, near Loughborough, by Colonel Dashwood, but it has not been found possible to carry out the work of summarising his observations in time for inclusion in this article.

The station at Belvoir Castle, maintained by the Duke of Rutland, K.G., began observation of rainfall in 1855, of temperature in 1896, and of sunshine in 1906. Averages of these elements, weighted to the standard period, 1881–1915, are printed in the *Book of Normals*, Section I. In the case of temperature (maximum and minimum and mean), averages for the period 1901 to 1930 have recently been computed, and I am enabled to include these by permission of the Director of the Meteorological Office. The observations at Lutterworth refer to the period 1921 to 1932.

RAINFALL.

The mean annual rainfall of Leicestershire varies from about 23 in. near South Wigston to nearly 29 in. on the high land in the Charnwood Forest area. Only a small portion of the county has an annual fall exceeding 27·5 in. Table I shows the mean monthly and annual totals (referred to the epoch 1881–1915) at three stations, from which long records are available. It will be seen that October and August are the wettest months, April and February the driest. In Table II the rainfall at Belvoir Castle is dealt with in greater detail. The average annual number of days of rain (0·01 in. or more) is distinctly higher than at other places, such as Camden Square, London (163), Shrewsbury (166), Oxford (168), Hull (185), Wakefield (165), and Portland Bill (163), where the rainfall is about the same as at Belvoir Castle. Rain occurs on about two days out of three in October, November and December, and is least frequent in June, when days without rain outnumber days with rain in the ratio of three to two. The wettest months of any name were July 1880, and July 1932, in each of which the fall was 6·59 in., or 271 per cent. of the normal July total. Reckoned as a percentage of the normal for the month, the rainfall of April 1920 (329 per cent. of the normal) occupies first place. The driest months were February 1891, and March 1929, in each of which the fall was only 0·07 in. The highest yearly total, 35·73 in., or 142 per cent. of the normal, occurred in 1882, and the lowest, 16·05 in., or 64 per cent. of the normal, in 1921. From data given by Dr. J. Glasspoole,[1] it appears that the standard deviation of annual rainfall over Leicestershire is rather more than 18 per cent. of the annual total. The heaviest rainfall in a day (24 hours to 9 h.) occurred

[1] 'The relation between annual rainfall over Europe and that at Oxford and at Glenquoich,' *British Rainfall*, 1925, pp. 254–269.

on August 6, 1922, when 3·62 in. was measured. At Leicester on that day, 2·15 in. fell in 12½ hours.

At Lutterworth the driest month was June 1925, with a fall of 0·06 in., and the wettest, May 1932, with 5·62 in. Mr. Binns points out that the driest spells of weather and also short heavy downpours associated with thunder usually occur with winds in the north-east quadrant.

TABLE I.—MONTHLY AND ANNUAL RAINFALL (1881–1915).

	Kebworth Beauchamp.	Thornton Reservoir.	Belvoir Castle.
Latitude	52° 32′ N.	52° 39′ N.	52° 54′ N.
Longitude	1° 0′ W.	1° 18′ W.	0° 47′ W.
Height above M.S.L.	390 ft.	371 ft.	259 ft.
	In.	In.	In.
January	1·90	1·98	1·77
February	1·69	1·67	1·67
March	1·78	1·84	1·81
April	1·67	1·70	1·53
May	1·88	2·01	2·11
June	1·94	2·16	1·91
July	2·58	2·48	2·43
August	2·72	2·80	2·62
September	1·87	1·81	1·87
October	2·82	2·81	2·70
November	2·26	2·26	2·23
December	2·56	2·68	2·46
Year	25·67	26·20	25·11

TEMPERATURE.

The only long series of temperature records available for reference is that for Belvoir Castle, going back to 1896. Table III shows the mean monthly and annual value of daily maximum and daily minimum in the 24 hours to 21 h. and the mid-temperature computed as half the sum of maximum and minimum, for the period 1901 to 1930, together with extreme values from 1896 to 1932. It may be noted that although on the average July is decidedly the warmest month, the highest recorded temperatures have occurred in August and September. In July, 90° F. has been reached on only one occasion, viz. July 10, 1921. A temperature below 32° F. in the screen has occurred in every month except July and August. The lowest recorded temperature, 7° F., occurred on January 17, 1926, during a noteworthy cold spell in which a grass minimum temperature below zero Fahrenheit occurred at several inland stations in southern England. The mean diurnal range of temperature is 14·2° F. The corresponding ranges at a few other inland stations at about the same height above sea-level are as follows: Rounton (Yorks.) 13·9° F., Little Massingham (Norfolk) 15·0° F., Woburn (Beds.) 15·3° F., Belper (Derby) 13·2° F., Coventry (Warwick) 15·2° F., Hereford 15·5° F., Ross-on-Wye

TABLE II.—RAINFALL (BELVOIR CASTLE).

	Average. 1881–1915.			Highest in Period 1855–1932.			Lowest in Period 1855–1932.			Greatest Fall in 24 hours to 9 h. 1896–1932.	
	Amount.	Percent. of Annual Total.	Days of Rain.	Amount.	Percent. of Normal.	Year.	Amount.	Percent. of Normal.	Year.	Amount.	Date.
	In.			In.			In.			In.	
Jan. .	1·77	7·1	19	3·77	213	1928	0·45	25	1880	0·91	6th, 1900 / 28th, 1927
Feb. .	1·67	6·6	16	4·29	257	1916	0·07	4	1891	0·98	16th, 1919
March	1·81	7·2	18	4·09	226	1916	0·07	4	1929	1·26	15th, 1920
April .	1·53	6·1	16	5·04	329	1920	0·28	18	1912	0·71	12th, 1923
May .	2·11	8·4	15	6·28	298	1889	0·51	24	1868	1·65	21st, 1932
June .	1·91	7·6	12	4·37	229	1927	0·13	7	1925	1·81	17th, 1905
July .	2·43	9·7	15	6·59	271	1880 / 1932	0·10	4	1868	2·40	13th, 1932
Aug. .	2·62	10·4	17	5·84	223	1857	0·46	18	1861	3·62	6th, 1922
Sept. .	1·87	7·4	15	5·05	270	1876	0·21	11	1865	1·30	14th, 1923
Oct. .	2·70	10·8	20	6·05	224	1880	0·54	20	1931	1·53	21st, 1924
Nov. .	2·23	8·9	22	4·46	200	1929	0·47	21	1867	1·06	18th, 1916
Dec. .	2·46	9·8	20	6·07	247	1868	0·19	8	1873	2·20	30th, 1900
Year .	25·11	—	205	35·73	142	1882	16·05	64	1921	3·62	Aug. 6th, 1922

15·4° F., Cheltenham (Glos.) 14·6° F., Reading (Berks) 15·6° F. The extreme values recorded at Lutterworth in the period 1921 to 1932 slightly exceeded those for Belvoir Castle, but do not otherwise call for special mention.

TABLE III.—TEMPERATURE (BELVOIR CASTLE).

	Mean Max.	Highest Daily Max. (1896–1932.)		Mean Min.	Lowest Daily Min. (1896–1932.)		Mid-Temperature ½ (max. + min.).
	° F.	° F.		° F.	° F.		° F.
Jan.	43·6	57	1st, 1916; 9th, 1921; 1st, 1922	33·7	7	17th, 1926	38·7
Feb.	44·2	62	10th, 1899	33·1	9	7th, 1917; 14th, 17th, 1929	38·7
March	48·1	69	23rd, 1918; 28th, 1929	34·5	13	9th, 1917	41·3
April	53·0	75	22nd, 23rd, 1901	37·0	10	2nd, 1917	45·0
May	60·2	84	23rd, 1922	43·1	26	7th, 1917	51·7
June	65·1	86	16th, 1896; 25th, 1921	47·5	31	8th, 1914	56·3
July	69·0	90	10th, 1921	51·5	35	11th, 1917; 1st, 1921	60·3
Aug.	67·7	95	9th, 1911	50·9	34	31st, 1919	59·3
Sept.	63·3	92	1st, 2nd, 1906	46·9	29	28th, 29th, 1919	55·1
Oct.	55·9	79	6th, 1921	42·0	23	27th, 1931	48·9
Nov.	47·4	63	2nd, 1927	36·0	15	24th, 1904; 14th, 1925	41·7
Dec.	44·0	59	4th, 1931	34·2	10	30th, 1908	39·1
Year	55·1	95	Aug. 9th, 1911	40·9	7	Jan. 17th, 1926	48·0

HUMIDITY.

Table IV gives the mean values of relative humidity and vapour pressure in millibars at Belvoir Castle for the 25 years 1896 to 1920, based on readings of dry and wet bulb thermometers at 9 h. and 21 h. The tabulations of hourly values of relative humidity at observatories show (*a*) that the average value of the relative humidity at 9 h. and 21 h. gives a close approximation to the mean for the day, and (*b*) that the

vapour pressure at 21 h. is on the average nearly the same as at the time of occurrence of the maximum temperature and minimum relative humidity. Consequently a close approximation to the mean value of the daily minimum relative humidity can be obtained from the relation

$$\text{Minimum R.H.} = \frac{\text{V.P. at 21 h.}}{\text{Sat. press. corresponding to max. temperature}} \times 200$$

Data calculated from this relationship are included in Table IV.

TABLE IV.—HUMIDITY (BELVOIR CASTLE, 1896–1920).

	Vapour Pressure.		Relative Humidity.			
	9 h.	21 h.	9 h.	21 h.	Mean of 9 h. and 21 h.	Mean Minimum.
	mb.	mb.	%	%	%	%
Jan. . .	6·9	7·1	93	91	92	74
Feb. . .	6·7	6·8	87	87	87	71
March .	7·3	7·2	88	88	88	63
April . .	8·2	8·0	80	84	82	58
May . .	10·4	10·1	77	84	80	57
June . .	12·5	12·3	77	84	80	58
July . .	14·1	13·9	78	85	81	57
Aug. . .	14·0	13·6	80	86	83	59
Sept. . .	12·5	11·6	83	88	85	58
Oct. . .	10·2	10·1	89	91	90	66
Nov. . .	8·1	8·2	91	91	91	73
Dec. . .	7·4	7·5	92	92	92	77
Year . .	9·9	9·6	85	88	86	66

The results show that Belvoir Castle experiences a high average moisture content of the atmosphere. From October to January the average relative humidity (mean of 9 h. and 21 h.) reaches 90 per cent. or more. The mean values of daily minimum relative humidity do not differ much from those computed for York.[2]

WIND DIRECTION.

Table V shows the percentage frequencies in each month, and the year of winds from the different points on the 8-point scale as determined from the observations at Belvoir Castle in the period 1896–1930. The

[2] 'The climate of York,' *Scientific Survey of York and District*, B.A., 1932.

results show the usual predominance of winds from south-west, particularly in the winter months. East winds are very infrequent, averaging only 2·5 per cent. North and north-east winds show a marked maximum frequency in the spring and early summer.

TABLE V.—WIND FREQUENCIES
(BELVOIR CASTLE, 1896–1920).

	Percentage Frequencies of Wind Direction (9 h. and 21 h.).								
	Calm.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.
	%	%	%	%	%	%	%	%	%
Jan.	10·3	5·9	4·1	2·3	5·9	17·2	32·0	13·1	9·3
Feb.	11·0	6·3	4·0	1·7	6·2	20·1	29·1	12·6	9·0
March	11·0	10·1	9·3	2·0	3·9	14·9	25·1	13·0	10·9
April	13·3	13·5	9·3	2·2	5·0	10·8	19·7	12·8	13·3
May	17·1	15·5	12·3	3·9	5·8	11·7	14·4	11·2	8·1
June	20·6	14·5	9·7	3·4	5·4	11·5	11·1	10·6	13·0
July	20·2	11·8	5·8	1·6	4·2	10·0	18·3	16·0	12·0
Aug.	20·8	9·1	3·3	1·2	3·7	13·0	23·7	15·6	9·6
Sept.	17·1	10·4	5·7	2·2	5·4	13·2	21·9	13·6	10·3
Oct.	16·0	7·4	5·2	3·1	5·0	20·0	25·4	9·2	8·6
Nov.	15·0	8·2	3·8	2·1	4·6	16·0	29·3	12·9	8·4
Dec.	12·1	4·2	2·7	2·1	5·1	20·4	34·1	11·6	7·6
Year	15·4	9·7	6·1	2·5	5·0	14·9	23·7	12·7	10·0

The station at Belvoir Castle is not well exposed for observations of wind force. From observations of the highest wind each day at Lutterworth, Mr. Binns concludes that January is the windiest month and September the quietest.

SUNSHINE.

In Table VI the first column of figures shows the mean daily duration of daylight in each calendar month. The second column shows the mean daily duration of sunshine, adjusted to the standard period 1881–1915, as registered by the Campbell-Stokes sunshine recorder at Belvoir Castle. The third column shows the mean recorded sunshine expressed as a percentage of the possible duration—that is to say, as a percentage of the value given in the first column.

May is the sunniest month, with an average daily duration of 6·55 hours, 42 per cent. of the possible amount, a value which compares favourably with the records at other inland stations. The winter sunshine at Belvoir Castle is relatively abundant, being exceeded only at stations on the

east and south coasts. The yearly mean daily duration, 4·21 hours, is compared below with corresponding data for other inland stations.

Belvoir Castle	4·21 hours
Cockle Park (Northumberland)	3·89 ,,
York	3·46 ,,
Cambridge	4·29 ,,
Rothamsted (Herts)	4·22 ,,
Harrogate	3·91 ,,
Sheffield	3·61 ,,
Nottingham	3·63 ,,
Oxford	4·13 ,,
Cirencester	4·13 ,,
Greenwich	4·05 ,,
Stonyhurst	3·64 ,,
Bath	4·33 ,,

The mean value for the 'Midland Counties' district, as defined for official climatological purposes, is 3·82 hours, a value exceeded at Belvoir Castle by 10 per cent.

TABLE VI.—SUNSHINE AND MISCELLANEOUS PHENOMENA (BELVOIR CASTLE).

	Sunshine, 1881–1915.			Mean Number of Days of :				
	Mean Length of Day.	Bright Sun-shine.	Per cent.	Snow, 1896–1930.	Snow lying, 1913–1930.	Hail, 1896–1930.	Thunder, 1896–1930.	Ground Frost, 1908–1930.
	Hrs.	Hrs.	%					
Jan.	8·12	1·74	21	4·1	2·5	0·3	0·1	16·3
Feb.	9·77	2·62	27	3·9	1·6	0·5	0·3	15·7
March	11·78	3·58	30	5·1	1·4	1·2	0·7	14·5
April	13·88	5·50	40	1·7	0·4	1·1	1·4	11·5
May	15·73	6·55	42	0·3	0	0·8	3·2	4·1
June	16·75	6·37	38	0	0	0·3	3·9	0·9
July	16·29	6·23	38	0	0	0·3	4·0	0
Aug.	14·67	6·00	41	0	0	0	3·9	0
Sept.	12·66	4·83	38	0	0	0·2	1·3	1·2
Oct.	10·58	3·35	32	0·1	0	0·3	0·8	7·0
Nov.	8·68	2·23	26	1·4	0·3	0·3	0·2	13·9
Dec.	7·60	1·45	19	3·1	0·9	0·4	0·1	14·4
Year	12·22	4·21	34	19·8	7·1	5·7	19·9	99·5

Miscellaneous Phenomena.

The right-hand portion of Table VI shows the mean monthly and annual frequencies of days of snow, snow lying, hail, thunder and ground frost as observed at Belvoir Castle. A day of ' snow lying ' is defined as one on which more than half of the country surrounding the station is covered with snow at the time of the morning observation. A day of ground frost is one on which a minimum thermometer exposed on short grass registers 30·4° F. or below. Similar data for other stations are given in the *Book of Normals*, Section IV. The frequency of days with snow has varied from 3 in 1928 to 53 in 1917, in which year there were 44 days of snow lying. There were 39 days of snow in 1919 and 37 in 1906. Hail is relatively infrequent, but occurs most often in the spring months. Thunder, with an average frequency of 20 days a year, occurs more often at Belvoir Castle than at any other British station for which the data are available, a fact which seems to indicate that Leicestershire is in the region of maximum thunderstorm frequency for the British Isles. As is commonly the case in the Midlands and the south-eastern half of England, the months giving the highest frequencies of thunder are the summer months from May to August.

Ground frost is frequent but not remarkably so, considerably higher frequencies being observed at some other inland stations. During the year 1932, for instance, there were 184 ground frosts at Rickmansworth (Herts), 132 at Sprowston (Norfolk), 131 at Chelmsford (Essex), and 135 at Ascot (Berks), as compared with 95 at Belvoir Castle.

VI.

FARMING IN LEICESTERSHIRE

BY

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Rock formations—General Characteristics of County—Soils—Management of Grassland—Vale of Belvoir—Western Area—Melton Mowbray Area—Agricultural Statistics—Decline in Arable Land—Crops and Grass—Cattle—Sheep—Pigs—Horses—Cereals and Potatoes—Permanent Grass—Agricultural Holdings—Agricultural Workers.

The agriculture of a county is largely determined by its geology and climatological conditions. If we take a brief general survey of Leicestershire, we shall find the rocks fall into five broad divisions :

(1) In the north-west rises the hilly, almost mountainous region of Charnwood Forest, composed of very ancient igneous and metamorphic rocks.

(2) Westward of Charnwood Forest and extending across the western boundary of the county into Derbyshire, the coal measures, with their accompanying beds of grit, shale and limestone, form the region known as the Leicestershire Coalfield.

(3) 'Red Rocks' of Triassic age form much of the land north, east, south, and south-west of Charnwood, covering, in fact, the greater part of the western half of the county. The river Soar may be regarded as the eastern boundary of this division.

(4) In the eastern half of the county, stiff bluish clays of Liassic age preponderate, with a hard bed of marlstone, whilst above them in the extreme north-east, and in one or two outlying patches elsewhere, sand and limestone of Lower Oolitic age are found.

(5) Lastly, scattered in varying thickness and with great irregularity over all the rocks mentioned, there are beds of clay, gravel, and sand, with occasional boulders of varying size which are described as 'Drift'—relics of the last glacial period, or Great Ice Age, when the Midlands were covered with sheets of ice. The alluvial deposits in the valleys of the main rivers are extensive and give rise to fairly rich soils which are liable to repeated and extensive flooding.

Geological Characteristics.

The nature, composition, and arrangement of the underlying rocks have a most important bearing upon the formation of soils as well as their subsequent cultivation. The average rainfall of the Midland area is by no means high, and the general topography of Leicestershire is that of a gently undulating county, which only rarely exceeds 600 feet above sea-level. Though the county does not possess many large rivers it has a large number of well-distributed small streams of great value to the farming industry; these serve as tributaries to the Soar, Welland, and Wreake, which are the main rivers in the county. It should be noted, however, that at certain points on the county boundary the rivers Trent and Avon are reached, though only over limited distances.

Soils of the County.

The soils of the best grazing area are varied. The eastern half of Leicestershire and part of Northants and Warwick lie chiefly upon the lower Lias clay, and soils from this formation are to be found in the valleys, as in the Vale of Belvoir, where many excellent pastures lying directly on the Lias clay are to be seen. The outcrops of the middle and upper Lias generally appear upon the gently rising slopes and summits of the rounded hills. Over the whole of the Lias formation, and especially in the more elevated parts of this roughly defined Midland area, varying expanses of boulder clay are met with and patches of glacial drift are not uncommon. These give rise to soils of a sandy and gravelly character, usually supporting a herbage of only moderate quality, but generally making good land for the rearing and growth of store cattle and sheep; and occasionally the best of this type of land will fatten heifers quite satisfactorily.

In the Market Harborough district many gradations of soil from a tenacious clay to medium loams are met with, most of which, in the hands of experienced graziers, produce beef and mutton of the very best quality. Some of the best old pastures have been down in grass for a large number of years. We know very little as to the conditions under which these pastures were seeded—probably they were self-sown, or it may be, in those far-off days when enclosure took place, the natural grass and clover seeds were used, and these were probably obtained from the bottoms of haystacks ; at any rate, we have no definite knowledge about the early conditions under which these famous grasslands were sown down. But in recent years much valuable scientific data relating to the chemical composition of the soils and the botanical character of the herbage has been obtained, and in addition there is also much practical information available as to the system of management pursued on these pastures which has been carefully recorded by several observers during the last hundred years. The best of these pastures have received very little more than the droppings from the sheep and cattle which have grazed them, many of them have never received fertilisers of any description, they have never been mown, and cakes or other concentrated foods have very rarely been used, and then only for a very limited portion of the grazing period. When the soils are examined, analyses show that they are in a fertile condition, usually rich in phosphates, potash, lime and nitrogen, and similarly the analysis of the herbage shows that the soil fertility is reflected in a herbage of superior quality, and surprisingly simple in its composition in so far as the species of herbage plants are concerned. The truth is that the finishing of full-grown cattle and sheep on this land does not make a serious demand on those constituents of the soil upon which fertility depends. These pastures have always been heavily stocked and well grazed, and consequently there is rarely any indication of anything in the nature of ' tuftiness ' or matted conditions of surface ; the constant trampling by cattle and sheep maintains the surface soil in excellent condition. The scythe may occasionally be used to mow coarse or strong-growing patches, and this helps to keep the pastures uniform ; and in addition great care is taken to spread evenly all manurial droppings, a process known locally as ' clot knocking.' In years gone by it was a common practice to collect ' clots,' which were carefully preserved and spread over the weaker portions of the pasture during the following autumn and winter months. The fences, mainly whitethorn, are well kept, and a special feature is made of providing well-constructed drinking-places for the grazing stock. Thistles are kept under rigid control by spudding and pulling : local blacksmiths make a special kind of implement for the purpose of pulling thistles which is very effective.

Management of Grassland.

The management of the grassland in this area is of a distinctly high character ; it is, in fact, a fine art—the grazier's art—which has done so much to make the Harborough district famous. Its graziers possess an unrivalled knowledge and judgment of the merits of grazing cattle and

sheep. The occupation of the grazier is one of very great interest, and whilst perhaps not so strenuous as arable or dairy farming it offers considerable variety. The management of land and stock occupies the grazier's close attention for a considerable portion of the year, but opportunities for relaxation are usually sought in the hunting field during the winter months ; many good graziers are ardent supporters of fox-hunting, and excellent horses, both hunters and shires, have been bred in the Harborough country.

The chief breeds of cattle grazed in the Market Harborough district include Shorthorns, Lincoln Reds, Herefords (pure and crosses), Devons, Aberdeen Angus, and Angus and Shorthorn crosses, whilst the sheep are usually crosses of Suffolk or Down breeds crossed usually with Border Leicester, Cheviot or half-bred or Mashams. These make excellent grazing sheep and during recent years have become exceedingly popular.

During the early part of the grazing season 1931, the following notes were made in order to show how some of the best grazing fields were stocked about the end of May or early June in that year :

Field.	Acreage.	Bullocks.	Sheep.
1	9·0	9	12
2	5·7	8	—
3	28·0	27	25
4	13·6	14	14
5	16·2	20	22
6	14·4	18	22
	86·9	96	95

The foregoing table shows clearly that the stocking of good pasture land is very heavy and has much to do with maintaining these pastures in a condition of high productivity.

The Vale of Belvoir.

The Vale of Belvoir in the north-east of the county is mainly given over to the grazing of cattle and sheep and the production of milk, which is partly sold for the liquid milk trade, though a very great proportion is used in the manufacture of the famous Stilton cheese for which the Vale is well renowned. The Sixhills district comprises a wide area of land of moderate quality, mostly in grass, and here milk production and the rearing of young stock is pursued in conjunction with the breeding of sheep.

The Western Area.

The western half of the county is given over to farming of a rather more mixed character. On the ploughed land, wheat, oats, barley, beans, sugar-beet, mangolds, and other green crops such as cabbage and kale are grown, but the majority of the farms are mainly devoted to milk production. In rather scattered and isolated areas Leicestershire cheese is still made, though not to the same extent as in former years. With

regard to sheep, it is a remarkable fact that the famous breed of Leicester sheep is not found in the county ; this breed, which is popular in many parts of this country and has also a great reputation in the colonies, was the outcome of the work done in breeding by the famous Robert Bakewell, who was born and died at Dishley Grange, near Loughborough (1726–1795). The last pure-bred flock of Leicester sheep was kept for many years at Beau Manor, near Loughborough, but this flock was dispersed several years ago. Bakewell also did much to improve the breed of Longhorn cattle, and whilst there are no herds of this breed in this county, it is well to note that the work he carried out at Dishley in the eighteenth century had much to do with laying the foundations of a system of farm live-stock breeding for which Great Britain has become deservedly famous.

The Melton Mowbray Area.

There is also marked agricultural activity all round the famous hunting centre of Melton Mowbray. Here excellent grazing land is to be found, and to the north-east considerable areas of ploughed land on the red soils of the middle and upper Lias. More limited in extent but under the plough are the lighter soils on the Northampton sands and Lincolnshire limestone ; here sheep and arable farming are closely connected. During recent years good progress has been made in this district in the application of co-operative principles to the business of marketing agricultural produce. The Farmers' Co-operative Association controls an extensive business which deals with the disposal of cattle, sheep, pigs and poultry ; a successful National Mark egg depot is also in operation which has done much towards developing a keen interest in the extension of the poultry industry, and most of the eggs produced are now graded and sold under the National Mark and through a progressive collecting depot. The Association also conducts a butchery business very successfully, and for this purpose the animals are supplied by its members. Agricultural co-operation has had a chequered experience in this county, but it is gratifying to note that co-operation amongst farmers at Melton Mowbray, Long Clawson, and other places in the Vale of Belvoir has been very successful. Progress at most of these centres has been largely due to enthusiastic leaders who possessed a wealth of energy and sound practical judgment, and have been imbued with a keen desire to be of service in securing the improvement of marketing conditions. The country to the south and south-west of Melton Mowbray is mainly in grass and on the whole well farmed, and is of a gently undulating character. This area comprises the land over which the famous Quorn pack is regularly hunted. Lying still further south is the almost equally famous Fernie country occupying much of what is called High Leicestershire, and centring round Billesdon Coplow. Both ' countries ' consist of rolling uplands requiring the best of horses and horsemanship, and some excellent hunters are bred and trained in these areas.

Agricultural Statistics for Leicestershire.

Like the farming in most counties, that of Leicestershire has undergone many changes, and the following statistics have been chosen with

the object of showing the nature and extent of such changes, especially with regard to cultivated land and the fluctuation in crops and stock.

Total area (excluding water) . .	1932	530,642	acres
Total acreage under crops and grass .	1932	457,930	,,
Rough grazings	1932	3,672	,,

Decline in Arable Land.

Year.	Acreage.
1870	179,892
1875	176,249
1895	120,854
1914	96,977
1919	131,023
1923	107,962
1926	92,189
1932	73,542

From the foregoing table it will be seen that during the last sixty years or so the arable area has decreased by over 100,000 acres. In more recent years, notably the period between 1919 and 1932, it shows a decrease of no less than 57,481 acres, and this in a period of only thirteen years. Even in the acreage under crops and grass there has been a serious decrease, owing, no doubt, to the extension of building schemes and other demands upon the agricultural area of the county.

The enormous change in the arable area has undoubtedly produced very great changes in the systems of the farming pursued and has had far-reaching effects on the social life of the country side. Broadly the results have been a serious and steady decline in the numbers of the rural population and consequently the local and allied industries such as those of the blacksmith, wheelwright, and saddler have also declined and in some districts have disappeared entirely.

Generally speaking, grassland requires far less labour than arable land, and is usually less productive, though in the case of dairy farming the aggregate value of milk produced may well be greater than the value of the crops when the land was under the plough. The number of active farm workers in such cases may not be seriously less, but taking the situation as a whole, it is certain that this great change in arable farming has been accompanied by a very considerable decline in the number of agricultural workers. A still more serious feature of the decline in arable land is the fact that during the last ten years there has been an average annual decline of nearly 3,500 acres, equivalent to an area of about 5 square miles per annum.

Crops and Grass.

A steady decline in the acreage of crops and grass is also taking place and the figures show that there has been a decline of over 9,000 acres

during the last ten years, which means a serious encroachment upon the farming area of the county.

Year.	Acreage.
1923	460,978
1925	459,049
1926	456,306
1932	451,930

Cattle, including Dairy and Grazing Stock.

Between 1915 and 1923, the cows and heifers increased by 8,755. This increase was spread very evenly over every Petty Sessional Division and showed that the change over to milk production was taking place more or less throughout the county.

During the last ten years the number of cattle has not altered to any very serious extent, though there has been a steadily increasing tendency for farmers to extend their activities in milk production, and consequently dairy cows have further increased in numbers. As to breeds of dairy cows the Shorthorns are pre-eminent, though excellent herds of Jerseys, Friesians, and Ayrshires also exist in the county. The business of milk production has reached a very high standard and flourishing associations for milk recording and graded milk have been in existence for several years and have done excellent propaganda work. During recent years improved methods of feeding and equipment have been adopted, and over one hundred milking machines are now in regular use.

The breeding of good dairy cattle has been materially assisted by the Ministry of Agriculture's Live Stock Improvement Scheme, under which are placed at various centres in the county no less than thirty-four premium bulls. With regard to grazing cattle, a large proportion are bought as stores and brought into the county during the autumn and spring ; they comprise a wide range of breeds such as Shorthorns (both English and Irish). Aberdeen Angus, Devons, Welsh, Herefords, and their respective crosses are very popular with the Leicestershire graziers, but it should be here recorded that the grazing industry, like other sections of British farming, has experienced very difficult and unremunerative conditions during the last few years, and a careful analysis of live stock statistics show that a gradually declining number of cattle have been grazed in recent years. Improved prices would no doubt do much to improve the grazing industry.

The following table gives the figures of dairy and grazing stock and other cattle from 1923 to 1932 :

Year.	Head of Cattle.
1923	149,107
1925	161,049
1926	158,387
1932	156,996

Sheep.

Sheep have been steadily declining in the county for many years and between 1915 and 1923 there was a decrease of 59,798, but the following figures for the last ten years indicate that a steady recovery is taking place.

Year.	No. of Sheep.
1923	192,102
1925	234,170
1926	253,485
1932	312,490

Whilst there have been great changes from the plough to grass, the increase in the number of dairy cows limits the grazing area available for sheep, and for many years a steady decline in the numbers of sheep has been experienced. In 1923 the figures for sheep were the lowest ever recorded in the county.

Since that year there has been a steady increase up to the end of 1929, when sheep made reasonably good prices ; then came a sudden and serious depression in the price of wool as well as mutton. At the present time, however, the price of mutton shows a gradually improving tendency, though wool remains at a very poor price. The favourite breeds of sheep for a long period included Leicesters, Lincolns, and occasional flocks of Down sheep, such as the Oxfords, Suffolks, Dorset Horn, Hampshires, etc. The heavier breeds are gradually giving way to breeds of sheep which are more suitable for grassland conditions and recent years have seen considerable introductions of the half-bred, Border-Leicester, and Cheviot cross, pure Cheviots, Kerry Hills, Cluns, Mashams, and many crosses with Suffolk, Oxford, and Hampshire rams. There has been a tendency to concentrate upon the production of fat lambs, which have yielded, under good management, fairly satisfactory results. Recent prices of wool have not been encouraging, but should an era of better prices set in, it may be safely prophesied that the sheep population will continue to increase, but it is extremely probable that any such extension will be almost entirely amongst breeds suitable for grass feeding.

Pigs.

The variation in the numbers of pigs in Leicestershire is shown in the following table :

1923	23,547
1925	22,625
1926	16,947
1932	28,776

The pig population of Leicestershire was much greater in the years when larger quantities of Stilton and Leicester cheese were made. The whey, a by-product in cheese making, is a very useful addition to the usual meals used for pig feeding, but with the decline of this by-product pig feeding became a less attractive section of farming, and the increase of imported bacon was also a powerful factor in steadily limiting the

production of bacon pigs. In the vicinity of our manufacturing towns there has always been a ready market for porker pigs, and whilst prices have fluctuated—at times violently—the pork trade has maintained a moderate degree of steadiness in the matter of price.

The more popular breeds have been the Large White, Middle White, Berkshire, Large Black, Tamworth, Wessex, Welsh and many indiscriminate crosses. A growing interest in pig breeding is being steadily stimulated by the pig-marketing scheme which is now before the country, and which will doubtless be adopted and put into operation about August this year. This scheme offers a price for bacon pigs which is definitely associated with the price of feeding stuffs, and, moreover, the price is such as to practically guarantee a definite market for all bacon pigs of suitable breeding and weight, with little or no risk of loss. The pig population recorded in 1932 was the highest during the last ten years, and under the new reorganisation scheme there is every prospect of the pig industry extending upon a very considerable scale. The British pig breeder can do much to supply a greater proportion of the bacon consumed than heretofore. In preparation for developments the County Milk Recording Society has started a litter recording scheme which is meeting with a fair amount of support from progressive pig breeders. The object of the scheme is to help breeders to select their breeding stock with a greater degree of confidence than has been possible in the past. There are twenty pedigree boars in the county under the Live Stock Improvement Scheme of the Ministry of Agriculture.

Agricultural Horses.

The reduction in the numbers of horses in the county is shown in the following table :

1923	23,519
1925	21,084
1926	19,855
1931	16,249
1932	16,061

The influence of the machine age is clearly evident in the foregoing figures, for it will be noted that a steady but relentless decline in the number of horses is in operation. In past years, Leicestershire has held a well-merited reputation for breeding some of the best shire horses, and for many years Leciestershire breeders have always occupied excellent positions in the list of awards at the Shire Horse Show in London. It is also a noteworthy fact that some of the most successful breeders of shires have been tenant farmers, many of whom have been ardent supporters of the activities of the Melton Mowbray Shire Horse Society. This Society has contributed materially to the development of horse breeding, and has readily paid very high premiums for the hire of some of the best stallions. The breeding of hunters is keenly pursued, especially by farmers and others interested in hunting, and for many years King's Premium stallions have been available. The undulating character of the county and its strong and well-laid bullock fences necessitates the breeding of a type of

hunter which must have not only great powers of endurance, but well up to average as a weight carrier, and, in addition, possessed of great speed and a clever jumper. The nature of the country and the character of the fences necessitate horsemanship of a very high order, and the hunting 'countries' of Leicester may well claim to have provided for many long years some of the very best training grounds for cavalry officers and all others who desire to excel in that noble art of riding 'straight' to hounds.

CEREALS AND POTATOES.

	1875.	1923.	1925.	1926.	1931.	1932.
Wheat . .	44,404	25,298	19,786	21,126	13,599	14,185
Barley . .	33,493	8,521	7,162	5,271	3,864	3,406
Oats . .	20,866	19,285	17,967	17,593	15,578	13,525
Potatoes . .	1,533	2,050	2,499	2,521	2,332	2,798
Total acreage .	100,296	55,154	47,414	46,511	35,373	33,914

From the foregoing table it will be seen that the decline in the acreage of cereals in the last fifty-six years amounts to very nearly 70,000 acres, and that during the last ten years a decrease of no less than 21,000 acres has to be recorded. The low prices of cereals during recent years have been such that arable farmers have been compelled to limit the acreage, so far as they could consistently do so, keeping in mind the requirements of the farm so far as the straw for bedding was concerned. Of the three cereals a decline of barley and oats was inevitable, and the slight increase in the acreage of wheat is undoubtedly due to the stimulating influence of the wheat quota. During the last ten years the acreage of potatoes has gradually increased, and under the new marketing scheme for potatoes it is very probable that the potato acreage in future may increase still further. Crops of mangolds and swedes, during recent years, have shown a marked tendency to decline in acreage, but this decline has been practically met by the increase of crops of marrow-stemmed kale, cabbage, and, notably, sugar beet.

During the last ten years the interest in the growth of sugar beet has been steadily increasing; this crop has the advantage of being one that the farmer can turn directly into cash, and, in addition, the tops and crowns provide a very useful fodder. Sugar beet growers are also entitled to receive a proportional supply of dried beet pulp at a preferential price. Dried beet pulp has been proved to be an excellent food for dairy cows and other farm live stock.

PERMANENT GRASS.

	1923.	1925.	1926.	1931.	1932.
Not for hay .	254,827	265,606	263,100	261,220	273,280
For hay .	98,189	95,544	100,948	115,004	107,108
	353,016	361,150	364,048	376,224	380,388

With the gradual decline of the arable acreage it is natural to expect that such decline would be reflected in the increase of grassland, and from the above table it will be seen that a steady increase in the permanent grass acreage has taken place during the last ten years, and, in addition, there has been a gradually increasing area mown each year for hay, this being necessary for the increased number of dairy cattle which have to be wintered indoors, with the consequent need for more bulky fodder. The acreage under permanent grazing has not only increased, but during the last ten years there has been a decided advance in the management of grassland. Surface cultivation coupled with liberal phosphatic manuring has done much to increase the stock-carrying capacity of the pastures. The use of fertilisers has also assured heavier crops of hay of a superior feeding value, the value of a high quality hay being now more fully recognised by progressive dairy farmers. The soil and climatic conditions of the county are extremely favourable for the development of good grassland, and these natural advantages are being more fully utilised each year.

Total Number of Agricultural Holdings.

1923	6,526
1925	6,460
1926	6,336
1931	6,050
1932	6,008

Holdings above 1 *Acre and not Exceeding* 50 *Acres.*

1923	3,832
1925	3,765
1926	3,650
1931	3,310
1932	3,246

During the last ten years there has been a decline in the number of agricultural holdings to the extent of slightly over 500. It is not possible to analyse fully all the causes of this decline but doubtless the demands for building sites of various kinds and public improvements have played an important part.

It will be noticed that there has been a decline in the number of small holdings, and whilst there has been much said in recent years about the necessity of small holdings, it will be seen that during the last ten years there has been a decline in the number of holdings above 1 acre and under 50 acres of no less than 586 holdings in this county.

This result would seem to support the idea that there cannot be a real and substantial reason for increasing the number of such holdings. It may well be that this result is due to the difficult times which agriculture has experienced during the last few years. Better times may possibly stem this unfortunate decline, for it is admitted on all hands that the finest asset a nation can possess is a healthy, numerous, and rural population, a virile and prosperous countryside. It should be noted that no less than

54 per cent. of the holdings in the county are under 50 acres in extent, veritably a county of small holdings.

Regular Workers.

1923	8,218
1925	8,118
1926	8,196
1931	7,439
1932	7,227

(Excluding the occupier and his wife and domestics.)

Total Workers, Regular and Casual.

1923	9,957
1925	10,062
1926	9,951
1931	8,477
1932	8,269

When we come to consider the common problem associated with the drift of agricultural workers to the towns, the figures in the foregoing tables emphasise a tendency which has often been deplored by all who have the welfare of the countryside at heart. Of the regular workers in agriculture in the county there has been a decline of no less than 1,091 during the last few years, and the figures seem to suggest that the decline has by no means been arrested. The same tendency is also seen when the total number of regular and casual workers is considered. If any evidence were required as to the seriousness of the agricultural depression which has extended over the last ten years, it is amply provided by this brief review of Leicestershire farming.

VII.

THE INDUSTRIES OF LEICESTER

BY

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The Hosiery Industry.—Introduction—State of Employment—Early Period—Introduction of Machinery—Materials Used—Purchase of Raw Materials—Processes—Machines Used—Labour—Marketing—Piece-work—Technical and Art Training.

Boot and Shoe Industry.—Mass-production—Invention of Machines—Domestic System—Raw Materials—Specialisation—Processes—Statistics—Relations of Employers and Employed—Wages—Agents and Merchants—Women's Shoes.

Engineering Industry.—Products—Hosiery Machines—Elastic Web Industry—Shoe Machinery—Machine Tools—Quarry and Roadstone Machines—Wood-working Machines—Heating and Ventilating—Scientific and Optical Instruments and Photographic Lenses—Electric Clocks—Cardboard Boxes—Typewriters—Technical Training.

Subsidiary Industries and other Industries, including Printing.

The popular slogan which avers that 'Leicester clothes the world,' doubtless owes its origin to a sudden consciousness of local patriotism strengthened by the city's relative prosperity in a world of economic depression. As a statement of tendency and as a reference to the multiplicity of trades established there, the boast is true and invites analysis, as affording a possible explanation of this prosperity. Of the population of 239,000, nearly 50 per cent. (115,000) are insured workers, of whom 65,000 are men and 50,000 women. This percentage, in respect of both men and women, is nearly double the average percentage for the whole of the country, and indicates that the purchasing power of the working-classes in Leicester, other things being equal, must be approximately twice as great as that of the 'average' worker for the whole country. Other things, however, are not equal. At the beginning of the present year about 16,000 men and women in Leicester were unemployed, a proportion (14·4 per cent.) which compares very favourably with the national percentage of 21·5. Some explanation of these figures is to be sought in the nature of the two staple industries on which the economic life of the city and county depends. If food and rent together constitute a 'first charge' upon income, clothing and footwear are none the less to be included among primary necessities. Further, the fact of the existence of two staple industries exerts, even in normal times, an important influence on local conditions. It is true that these trades are seasonal and that their 'off' seasons usually coincide; it is also true,

however, that in a long period consideration a non-seasonal depression in the hosiery industry rarely corresponds in time to a non-seasonal depression in the boot and shoe industry. There has thus grown up in Leicester a considerable body of mobile labour capable of ready assimilation into either of these staple trades—a phenomenon relatively rare in industrial towns and possessed of very definite advantages.

The Hosiery Industry.

Since the time of King Alfred the scarps and meadows of Leicestershire have been recognised as highly suitable pasture lands for sheep, and even in that remote age crude textile fabrics were produced in both town and country. In the thirteenth century wool was spun by hand and woven into blankets and coarse fabrics, and wool fairs were held in Leicester.

In the sixteenth century a new industry had arisen ; wool-combers supplied the yarn they spun to persons willing to knit stockings by hand. The trade prospered, and about two thousand people were employed. Meanwhile in 1589 the Rev. William Lee of Calverton, Nottinghamshire, invented the hand stocking-frame, and in the early years of the following century the industry established itself in Leicester and Leicestershire. Although the frame-work knitters of London obtained a Charter in 1663, the trade gradually left London and developed in the Midlands. The eighteenth century witnessed a period of trade depression, and stockingers who had been earning from nine to eleven shillings per week were compelled to refund from two to four shillings for certain ' charges,' such as frame rent, standing room, light and fuel, winding, taking-in, deductions for faulty work, etc. The workers were even required to purchase the needles to replace breakages, and, before the passing of the Truck Act, were often forced to accept commodities in lieu of money. A large number of small stockingers' shops existed, and ' middlemen ' obtained yarn from the warehouses and knitted it into stockings, which they returned at the end of each week. This method of trading continued until the Industrial Revolution, when factories were erected and power machines introduced.

By about 1860 machinery developments had resulted in the construction of several types of machines, the chief of which were ' Cotton's Patent Frames ' in 1863 (which produced fully fashioned garments), circular loop wheel and sinker wheel machines, and, thanks to Matthew Townsend's invention of the latch needle in 1849, circular and flat latch needle machines. Cotton, who was born at Seagrave, Leicestershire, in 1819, invented his machine at Loughborough, whilst Townsend was a Leicester ' fancy hosier.' Since that time many improvements have been made in the mechanisation of knitting, and knitted fabrics are now used for all types of hose in both underwear and outerwear. The ' fancy ' trade was inaugurated in Leicester by William Kelly early in the nineteenth century, and although many different articles of apparel were knitted—gloves, cravats, franklins or jerseys, children's boots, etc.—the term ' hosiery ' still held its ground ; even to-day it is still used in a generic sense.

In the early periods of the trade each of the three knitting counties tended to specialise in the use of a particular material. As time went on, however, this distinction disappeared, although traces of its effect still exist. Thus as finer counts of cotton and silk could be spun, stockings of finer gauge were made in increasing quantities in Nottinghamshire and Derby, and this tendency still holds in a lesser degree to-day. Similarly, as fancy hosiery is more often made of wool, that trade increased more rapidly in Leicester than elsewhere. To-day practically all textile materials are used for knitting—viz., cotton, wool, silk, rayon, acetate silk, and, to some extent, flax, ramie and camel-hair. Modern hosiery yarns differ considerably from those used in weaving, in that they have less ' twist ' and more fullness. Australian, Cape and Argentine wools are largely used, owing to their peculiar properties, although a certain amount of wool is spun in Leicester itself. Other yarns are spun in Yorkshire (wool), Lancashire (cotton), Warwickshire and Derbyshire (artificial silk), raw cotton is obtained chiefly from the U.S.A., Egypt, India, Brazil and Peru, and silk is imported from Japan and Italy.

In the purchase of these raw materials spinners do not as a rule approach manufacturers directly, but through agents. The latter call periodically on manufacturers, and may each represent a number of spinners. Orders for yarns are usually placed ' firm,' although orders for knitted goods are subject to cancellation. This system is somewhat disconcerting to manufacturers, but is said to have its compensations in regard to early placements of orders, and is still in being. The method of payment usually provides for one month's credit and a cash discount. The prices of yarns vary, of course, with fluctuations in raw material prices or tops. Hence a certain amount of speculation exists, and manufacturers follow raw material prices, crop reports, etc., with interest if not always with profit.

The cycle of processes involved in manufacture depends upon the type of garment to be produced. For our present purpose, however, we may regard the following operations as constituting the customary succession :

(*a*) Winding (and in some cases warping).
(*b*) Knitting (circular, seamless, fashioned).
(*c*) Seaming, linking, welting (closing operations).
(*d*) Cutting out and machining (making-up operations).

Mending is carried out on rough fabric and also on dressed fabric or goods. Scouring, dyeing, or bleaching and finishing may be carried out either on a fabric before it is cut out or after goods have been knitted to shape and seamed.

All goods are subsequently taken to the warehouse and paired (if necessary), folded, stamped, etc., and boxed ready for sale.

The machines used in the manufacture of hosiery do not require a large amount of power. Formerly gas, steam or oil engines were used, but modern practice prefers the electric drive. One horse-power is sufficient to drive eight sewing machines, four to six seamless hose machines, or three fabric machines. In some cases the motor is incorporated with the machine, but generally small groups of machines are driven from one

motor. This method effects a great saving in shafting, belts, etc., and total stoppages are therefore rare.

Although mass production of like articles is carried out as far as possible, the great variety of styles which prevails in single garments rendered the team system very difficult. If the fastest operation be taken as unity, the numbers of machines may be regarded as multiples of this in the production of a given garment, and the machines so arranged that a conveyor system becomes possible. A change in garment or style, however, necessitates a complete re-arrangement, and, in practice, the machines are often 'averaged' in order to take account of a more or less constant variety of articles. Factory planning has now developed to a high degree so as to ensure a flow of goods in a given direction.

Hosiery manufacture demands a large proportion of skilled and semi-skilled labour. The most highly skilled work is that of 'legging' fully fashioned silk hose of fine gauge, and this is usually done by men, while 'transferring' and 'footing' are done by mixed male and female labour. Seamless hose machines, web frames, and warp-knitting machines are operated by both male and female labour, usually by women during the day and by men during night-shifts. Winding, mending, seaming, linking and machining are carried out by women.

In dyeing and finishing, the light operations, such as turning, brushing, calendaring, etc., are carried out by women, but scouring, milling, dyeing, napping, pressing and boarding are usually done by men. A shortage of skilled labour sometimes occurs, owing to the custom of working shifts in a busy season.

There is no systematic method of training labour, no scheme of apprenticeship, for example, but youths and girls are first employed as assistants or 'runabouts,' and afterwards transferred to knitting or sewing machines. Opportunities for practice work are afforded by the Leicester College of Technology and by the colleges at Loughborough and Hinckley. This assists in some measure, although the conditions under which the work is done do not approximate very closely to those of the factory.

The earlier system of marketing, whereby wholesalers, after purchasing finished goods, distributed them to shopkeepers, still persists on a considerable scale. To-day, however, many quite small firms supply the multiple stores and large shops direct. In other cases, especially with large firms, manufacturers advertise their own goods and employ travellers or salesmen, both at home and abroad. Manufacturers' agents also assist in the distribution.

Within the factory the system of piece-work applies generally throughout the trade, although the time-rate is not unknown. Prices which were established before the war are still utilised as a basis, and to these is added a bonus which varies according to the cost of living. This plan has proved very satisfactory, and few disputes have taken place. Wages are high in comparison with those paid on the Continent and, of course, in the East, and the industry has been protected to some extent by the imposition of tariffs.

During recent years Leicester has developed a large knitting-machine building business, which has enabled manufacturers to benefit by the

installation of improved machinery ; several types of machines used are, however, still made abroad. The community, too, has benefited greatly by the introduction of knitted garments, which are cheap, efficient, hygienic, comfortable and stylish. In many cases woven goods have been replaced by knitted goods, so that Leicester has prospered at the expense of her competitors. On the whole, considerable enterprise has been shown in the development of new garments, new fashions and new designs. Nevertheless, in spite of statements to the contrary, the hosiery trade remains a seasonal trade subject to fluctuations of weather and fashion. As production is high and machinery developments are prodigious, severe competition at home and abroad is inevitable.

Both machine builders and manufacturers have realised the advantages of technical and art training, and at the local colleges combined courses have been instituted with success. At Leicester alone some 500 students attend courses in the Hosiery Department, and that in spite of the absence of any definite apprenticeship scheme. Of these, approximately 80 per cent. attend in the evenings, but signs are not lacking that more attention is being paid to the advantages of day training. In this and in other ways the Leicester and Leicestershire hosiery manufacturer is playing a worthy part in British trade. Fortunately or unfortunately, the hosiery industry lends itself to the establishment of small self-contained manufacturing concerns which may employ from 300 to 400 people without the necessity of instituting elaborate and costly systems. Thus personal contact is preserved between employer and employee, matters can be arranged quickly and satisfactorily, and rapid changes can be effected to follow the day's fashion. Businesses launched with comparatively small capital outlay may, by the use of modern methods, the purchase of modern machines, and the study of modern fashion and design, be developed quite successfully by sheer grit and hard work.

The Boot and Shoe Industry.

The history of the hosiery trade in Leicester and Leicestershire takes us back into the remote past ; both town and county have grown up in a ' tradition of wool,' and we acknowledge a certain fitness in the sequence of events on learning, for example, that on the site of the present Friar Mills there once stood the Monastery of the Black Friars of St. Dominic, themselves wool merchants as long ago as the early thirteenth century. In contradistinction to this, the story of boots and shoes is quite modern, and falls almost entirely within the last hundred years. A company of ' jornemen of schomakers ' existed in the days of Elizabeth, but it remains doubtful whether before 1830 the shoemakers of the town ever satisfied a wider need than that of its own inhabitants.

In long-period considerations of industrial growth we perceive the principle of development as a transition from the slow handicraft of many highly skilled individual productive units (a system characterised in its early stages by personal acquaintance between craftsman and customer) to the rapid mass production of mechanised industry, in which the craftsman is replaced by the ' machine minder,' and the customer becomes, at least for the workman, a generalised abstraction. This

development has taken place in the manufacture of boots and shoes. Its meaning is better seen if we consider the function of the shoe. Most feet, like most faces, appear to have their individual peculiarities of proportion, and a slight misfit, such as in clothing would pass unnoticed, is of vital importance in shoes. Again, the simple and inert rigidity of the last contrasts with the complex flexibility of the human foot. Herein lie the problems of the mass production of boots and shoes—to produce them by the million and to place them upon the market so that any one can walk into any shop and obtain a pair that will fit his own ' particular ' pair of feet.

Until 1790, when Thomas Saint invented a chain-stitch machine for sewing together the various parts of the upper, shoes were made entirely by hand, slowly and laboriously. While to-day some four hundred types of machines are in common use, the wider application of machinery to manufacture did not really begin before the middle of last century. Mechanisation, however, once established, made rapid progress. Walter Hunt's first lock-stitch machine (1832), improved by Elias Howe in 1846 and followed in 1849 by Allen Wilson's rotary hook principle, represents a further stage in the manufacture of the upper. Early in the century Randolph and Brunel had applied themselves to methods of riveting by machinery. Then Thomas Crick, the ' father of the Leicester shoe industry,' securing an iron plate to the sole of his last, clinched rivets, driven through the leather, against it. His son introduced the method of inside riveting, whereby uppers and insoles were riveted together, then turned and the sole attached. This was in 1853. In the same decade appeared the ' Blake ' sewer, whereby the outer and inner soles (the latter with upper attached) were sewed together, an invention which, by its revolutionary effects, heralds the modern period. The rest is a matter of detail—the ' clicking ' press, the eyeleting machine, screwing and heeling machines, edge-trimming machines, burnishing machines and so on, until the introduction of the hand-method lasting machine in 1885 completed the industrial revolution from hand to machine.

Under the Domestic System, when each worker's home was a law unto itself in the matter of hours and working conditions, when father and sons riveted and ' finished ' and the womenfolk performed the ' closing ' operations on crude treadle machines, when workshops were badly ventilated and insanitary, and tuberculosis was rampant, life was a frantic struggle, a demoralising experience. When this system, even under rapidly improving conditions, received its death-blow, after the national strike of 1895, and the present factory system firmly established itself, most people looked to the future with much confidence and little regret.

A century ago the raw materials of shoe production included horse-hide and ox-hide, the skins of sheep, calves and goats, and little else. To-day a wonderful variety of materials, drawn from all over the earth and made from scores of species of animals, birds, reptiles and fish, enters into the routine of large-scale manufacture. The canvas is too large for even the sketchiest of outlines.

Boot and shoe manufacture has thus become a highly specialised industry. Even so, few realise to what extent variety in choice of material

and multiplicity of styles and ' fashions ' have influenced methods of construction ; more than a dozen different manufacturing methods exist, each of which may involve some 150 distinct operations and, at least, 100 different machines. It is possible in this brief survey to refer only to a few of those major operations through which all boots and shoes must pass in the process of manufacture.

The making of the ' last ' model has remained a highly skilled craft through its defiance of the application of a formula. Its evolution owes much to the inventive genius of Leicester firms. Taking account in its form of every movement of the foot, to the end that movement shall be easy and natural, the last must yet be rigid in the shoe and mobile in removal. Dried Canadian maple wood is used. The rough block, weighing nine or ten pounds, is first shaped and trimmed until it satisfies the necessary conditions. This original is then used as a model in a turning lathe for the production of as many as are required. The necessary mobility has been attained by dividing the last into two parts, while its rigidity in the shoe depends upon the use of suitable devices inserted into the V-shaped aperture between the parts. The finished product weighs about a pound.

After last-making comes pattern-cutting, a process which calls for a high degree of skill in the correct placing of curves and seams in the upper in order to maintain the form of the shoe in wear, and necessitates further study of the shape of each part to effect economy in cutting.

' Clicking ' and ' closing '—the cutting out and the sewing together of the parts of the upper—and the accurate preparation of bottom stock are not merely automatic machine processes. While the old hand-sewer produced some ten or twenty stitches per minute and the early treadle machine about 300, the modern power-driven machine makes 3,000 stitches per minute, equivalent, in machines fitted with four needles, to 200 stitches per second—a truly amazing speed, and one which is eloquent of the deft touch of the skilful ' closer.'

But it is in the lasting and making departments that the genius of the modern machine finds its fullest expression. Here are machines which by means of mechanically operated pincers seize the flat-cut upper, stretching and drawing it to conform to the subtle curves of the last, and securing it by tacks or staples. Here are machines which imitate at high speed the ' welting ' methods of the old-time craftsman with awl and thread. Here, too, are machines which cut and drive thousands of nails a day. Every type of machine known within the industry operates in Leicester's factories. It was in no small degree due to the opposition in other parts to the introduction of machinery into factories that so many workers from these centres came to Leicester and placed their experience and skill at the disposal of local manufacturers.

The number of boot and shoe manufacturers in Great Britain is estimated at 950, with about 132,000 employees and an output of 117 million pairs per year. The comparatively recent industrialisation of manufacture partly explains why the industry is not confined to just one or two large centres, but has grown and developed in small towns and villages over a wide area. Despite this, Leicester is the greatest shoemaking centre in

the world, the industry supporting 30,000 operatives (of whom 20,000 are men) and producing an annual output of approximately 25 million pairs. The statistics of employers, employees and output for Leicester and county are 130, 350,000 and 40 million pairs respectively.

From the bitter fight between employers and employed in 1892 (the only serious dispute in Leicester in the history of the trade) emerged the Boot and Shoe Operatives' Union and the Federation of Boot and Shoe Manufacturers. The Arbitration Board (founded in 1878), which gathered strength from the same struggle, affords a notable example of how trade disputes may be amicably settled without recourse to strike or lock-out. This conciliatory spirit has been responsible for the almost entire absence of industrial disputes during the last forty years. Few large manufacturing centres can claim so happy a record.

The actual wages earned are good. For men of 22 years and over, as for women of 20 years and over, standard minima have been established, with the following graduated scales for boys and girls :

		s.	*d.*			*s.*	*d.*
BOYS :	Age 15 . . .	14	6	GIRLS :	Age 15 . .	13	0
	„ 16 . .	19	6		„ 16 . .	17	0
	„ 17 . .	23	0		„ 17 . .	21	0
	„ 18 . .	29	0		„ 18 . .	25	6
	„ 19 . .	35	6		„ 19 . .	31	0
	„ 20 . .	42	6		„ 20 . .	36	0
	„ 21 . .	53	0				
	„ 22 . .	60	0				

The National Conference Agreement provides that 'Piece-work or Quantity Statements shall be prepared on a basis to ensure the average worker earning not less than 25 per cent. over the minimum wage.' When employed full time, men may earn as much as £5 10*s*. or £6, and women from £2 10*s*. to £3 10*s*. per week. Piece-work is the usual basis of payment.

Agents and merchants, who supply manufacturers with their raw materials, owe their commanding position in the industry to the fickleness of fashion, which effectively frustrates manufacturers' attempts to place orders for any considerable period ahead or to produce largely for stock. This increasing inconstancy tends to cause the flow of orders to become more and more irregular and to result in alteration of periods of ' rush ' and of short time, tendencies whose ultimate influence may be reflected in comparatively high production costs. As in Leicester women's shoes form the bulk of the output, this tendency is marked.

While women's shoes make up the bulk of the output, there is also a very large production of boys' and girls' footwear and of sports goods. Leicester-made football boots have long been well known in the trade, while white duck and canvas shoes for tennis and other purposes are exported to all parts of the world. On the whole, it may be said that the great mass of production is for the ' medium ' and ' better medium ' trade, and aims at the making of good-wearing shoes at a reasonable price.

Despite the difficulty referred to above, of basing the commercial side of the industry upon long contracts owing to ever-changing styles, production in Leicester still takes place on so large a scale that each season's novelties, after separation into numerous categories, may be subjected to massed means of manufacture with the required economies of production.

Even the most rapid survey of the shoe industry in Leicester would be incomplete without some reference to the conditions which prevail in the factories and to the men and women who work in them. For in vivid contrast to the dark and dirty ' up-entry ' workshops of a generation or so ago are the bright and spacious factories of to-day, pure of air, warm, well-ventilated and clean. They are filled with ' operatives ' who do not merely take a decent interest in their exterior, but display pride in their work and a sense of progressive efficiency.

The Engineering Industry.

Engineering ranks third among the industries of Leicester. In addition to supplying and maintaining machinery for the boot and shoe and hosiery trades, the engineer in Leicester is responsible for the provision and upkeep of plant in many subsidiary industries. The following list will serve to show how diverse are his activities : quarrying and road-making machinery ; machine tools ; woodworking machinery ; heating and ventilating engineering ; box-making machinery ; hoisting appliances ; iron-founding ; constructional engineering ; optical instruments and fine measuring machinery ; clocks ; typewriters ; small electrical machinery ; printing machinery.

Leicester produces vast numbers of automatic hosiery machines. The evolution of the modern machine, from Lee's stocking-frame to the automatic or ' Straight Bar Machine,' and thence to the early circular knitting machine made by Thompson of Leicester and incorporating the latch needle of Matthew Townsend, also a Leicester man, is a fascinating romance. To every fresh demand of the hosiery makers of the country the machine builders of Leicester have responded ; indeed, in many cases, the machinery inventions have dictated the changes which have occurred in the design and production of hosiery wear.

Leicester can claim to be the birthplace of the elastic web industry, its craftsmen having journeyed to the Continent and America to teach the technique of elastic web weaving. The recent introduction of wide corset web and the use of artificial silk in the manufacture of elastic web necessitated both the adaptation of the Lancashire piece-goods loom to the industry and the invention of many new types of machines to deal with preparatory processes. These adaptations and inventions are, in many instances, the work of local engineers. The whole of the machinery necessary for the manufacture of shock-absorbing rings for aircraft was designed and produced in the engineering department of a Leicester firm. It is interesting to record that Mr. L. Rowland, B.Sc., A.M.Inst.C.E., a distinguished Leicester engineer, has been a member of the British Standards Committee on Rubber since its inception. Some years ago, when a member of the engineering staff at the College of Technology, he designed the standard machine used for the testing of rubber.

The story of another of Leicester's industries, the manufacture of boots and shoes, illustrates inventive genius. Leicester boot and shoe manufacturers have always encouraged machinery engineers and have been quick to place the very latest shoe-machinery in their factories. As some 400 different machines are used to-day in the manufacture of boots and shoes, the place of the engineer in this industry is paramount. Further, nearly the whole of the shoe factories of the British Empire are equipped with Leicester-built machines, while many machines are exported to foreign parts. In the section of this survey which reviews the boot and shoe industry reference has been made to types of machines used and to their evolution.

Specialisation in branches of engineering not immediately connected with Leicester's staple industries occupies the energies of many firms in Leicester and district. A number of firms, for example, specialise in machine tools, and mass production in the engineering workshop owes much to Leicester. Drilling machines, capable of drilling fifty-six holes at one operation, have recently been made in Leicester, and the products of the Leicester machine tool manufacturers are to be found in every large motor car works in the country.

Leicester lies at the apex of a wedge of igneous rock which provides granite for road-making, and granite quarries stretch from Mountsorrel through Whitwick, Bardon Hill and Cliffe Hill, southwards to Enderby, Stoney Stanton and Croft. These quarries, from which granite has been extracted since the earliest times, provide one-quarter of all the granite used on English roads, and Leicester has thus become the home of the quarry and roadstone machinery maker. Leicester-made breakers, granulators, crushing rollers, washers, driers, concrete and tarmacadam mixers are exported to every part of the world, and the manufacture of these machines provides employment for many hundreds of men. Leicester has earned the reputation of being one of the cleanest cities in the kingdom. Her road-making engineers, by their careful study of road surfaces, have contributed to this result. It is of interest to note that the modern concrete mixer and tarmacadam mixing machine originated in Leicester. There is also a considerable industry in the production of auxiliary quarry equipment, in sand and gravel washing, and in the manufacture of screening plant for concrete-making and of excavating plant for quarrying.

The engineers of Leicester have specialised for nearly thirty years in the making of woodworking machinery, including machines for sawing, mortising, tenoning, planing and moulding operations. Of special interest is the exceedingly ingenious machine known as the universal pattern miller, by means of which practically every pattern-making operation can be performed. The patterns both for the Rolls Royce Schneider Trophy engines and for the huge fans installed at the Ford works at Dagenham were produced in Leicester.

Heating and ventilating is a highly important branch of engineering in which Leicester specialises. The new Parliament building of Northern Ireland and the Shell-Mex edifice in London are two of the more recently erected structures of repute to be heated and air-conditioned by Leicester engineers. In addition, many of the most modern cinema theatres have

called upon Leicester for the installation of their heating and ventilation equipment. The quarrying, boot and shoe and woodworking industries require, of course, dust-extracting plant, and the satisfaction of this need has consequently become an associated branch of the work of specialists in heating and ventilation. Dust-extracting plant made in Leicester has been installed in industrial houses all over the world.

An industry in which Leicester stands as a pioneer, and one which has become peculiar to the town, is the manufacture of scientific and optical instruments and of photographic lenses. When it is stated that a Leicester-made lens has to fit a standard gauge to within a half-millionth part of an inch, the degree of precision in its manufacture will be realised. Some of the most accurate machines in the world must be those engaged in the production of optical instruments and measuring machines for which the city is famous. In view of the extraordinary degree of accuracy in screw-threads necessary in the manufacture of optical instruments, extensive research was an essential preliminary to manufacture. This research proved invaluable in the fixing of the British Standard Specification for screw-threads, and it can be truly said that many of our present standards emanated from Leicester. In addition, the majority of films exhibited in British cinemas are both produced and projected through lenses made in Leicester, while the greater proportion of projectors at Hollywood are equipped with these same Cooke lenses.

The largest electric turret clock in the world, that in the tower of the Singer building at Glasgow, was constructed by a Leicester firm which has specialised in bells, clocks and other electrical devices for sixty years. 'Pul-syn-etic' electric clocks are met with in every country in the world. Delhi is timed by 'Pul-syn-etic,' with five master clocks and 400 auxiliaries; while the new Parliament building at Belfast is equipped with 137 of these clocks. Electro-motor chiming gears for use in conjunction with the 'Pul-syn-etic' system constitute a further activity of the same firm, while travellers by Cunard and other lines will set their watches and take their meals by clocks made in Leicester. Thus can Leicester engineers claim to keep the world punctual.

There may be something coincidental in the fact that the multifarious industries of the city and county seem to agree upon the desirability of producing especially those classes of goods which the ultimate consumer insists upon receiving in cardboard boxes. Leicester, of course, makes her own boxes, and her many box-makers are, moreover, well served by local engineering firms engaged in the manufacture of highly ingenious machinery for that purpose. Box-making machinery from Leicester is despatched to all parts of the country, and a very satisfactory export trade is maintained.

Leicester possesses the largest typewriter factory in the British Empire. The modern typewriter, consisting as it does of some 2,000 parts, is a triumph of engineering skill, and one learns with interest that the Leicester firm of manufacturers permits a margin of error of only one-thousandth part of an inch.

The cordial relations which have long existed between the Engineering Department of the College of Technology and the engineers of Leicester

are attested by the large amount of experimental and investigation work which the staff of the department undertakes for industry. The splendidly equipped testing laboratory and the staff are thus available for all testing and investigation work received from local firms. The major portion of the equipment has been generously provided by the Engineering and Allied Employers' Leicester and District Association, the Leicestershire and District Munitions Committee's Engineering Education Fund, and the Leicester Association of Engineers.

The Printing Industry.

Leicester is accepted throughout the country as being a prominent centre for the production of printing of the higher class, especially colour printing. Within a small radius of the city there has grown up a body of manufacturers educated in the art of national distribution of their products, skilled in the application of branding to salesmanship, and fully appreciative of the value of modern printing. Their requirements are more fully met by the local members of the printing industry than elsewhere, and the standard of excellence established has attracted the attention of students and buyers of printing in all parts of the country.

Despite the unhelpful conditions prevailing generally, considerable progress is being made in the development of printing and printing processes. Fundamentally, there is more adequate provision of facilities for the technical training of printing apprentices. Steadily working over a number of years, executive and district committees have evolved systems of apprentice selection which are resulting in the introduction of a more intelligent and more highly educated type of apprentice. They have been helped in their work by the very favourable rates of remuneration in all branches of the industry.

In Leicester this problem is being solved by the Gateway Secondary School, which is unique in the kind of pre-apprenticeship training it offers to printers. In addition to a secondary education, specially selected boys are given practical instruction in the various branches of printing.

In Leicester, as in the other more important centres, day as well as evening training is provided for apprentices. Here the training is carried out in the College of Arts and Crafts—a fact that accounts in a large measure for the high artistic standard of local printing.

Conclusion.

The extremely varied character of the many subsidiary industries of the town and county renders a connected account quite impossible within the limits of space at disposal. More than seventy classifiable trades, many of which thrive with no apparent links to connect them, provide employment for thousands of workpeople.

It is interesting to observe that the two staple industries tend more and more to be independent of other areas, save in the provision of raw materials. The extremely large number of manufacturing processes involved and the derived demand for commodities, to be used again in further manufacture, have led to the growth of numerous subsidiary industries which, while remaining ancillary to the main industry, serve

a wide industrial field beyond the confines of the county. In respect of the shoe industry, for example, there are several thread factories, while local manufacture supplies nails, tacks, knives, wires, hammers, etc., in far greater quantity than is required for use in Leicester. Thus too do we explain the prosperity of local tanneries and of firms specialising (on the chemical side of the business) in the manufacture of dyes, stains, inks, waxes, cements, paints, and so on. A further step in the same direction brings us to an understanding of Leicester's unique position in boot and shoe distribution : hundreds of retail stores with branches scattered all over the country are owned and controlled by Leicester firms, who thus bridge the gap between manufacturer and customer.

The position with respect to the hosiery industry is very similar. Wool-spinning, the manufacture of cotton threads and of rubber latex threads, dyeing and finishing, box-making, needle manufacture, and so on, tend to make Leicester more and more independent of her neighbours, more and more self-sufficing.

Tyres for all types of vehicles, from perambulators to omnibuses and aeroplanes ; elastic web measured in miles, buttons in millions ; all sorts of celluloid articles ; fountain pens, dolls, cameras ; cigars ; pies and cheeses, confectionery ; ready-made suits ; show-cases, shop fronts, metal stands, electric signs ; umbrellas ; medical dressings and surgical appliances ; corsets, corselets, brassieres, girdles ; furniture, upholstery, cane goods . . . and so might one prolong the list. Versatility, a refusal to hang on to just a couple of staples—this is, it would appear, the interpretation of the group-mind of Leicester.

VIII.

MUNICIPAL ACTIVITIES OF LEICESTER

BY

H. A. PRITCHARD,

TOWN CLERK.

The Corporation — Water supply — The Derwent Valley Water Board—Gas undertaking—Electricity supply—Tramways and Omnibuses—Sewage disposal—Open spaces and recreation areas—Roadway development—Judicial Courts—Diocese—Civic status restored—Arms of the City.

It is now just a century since the Royal Commission was appointed to examine the then existing municipal corporations' activities, and it was in consequence of the famous Report of this Commission, generally known

as 'the postscript to the Reform Bills,' that municipal corporations were established as they exist to-day.

The ancient governing authority of Leicester passed into history, and on Saturday, December 26, 1835, the new Council was elected. 'Peace and honour be unto the memory of their predecessors. January 1st, 1836.' Thus reads the last entry in the Common Hall Books, the records of the ancient Chartered Corporation which had governed the town for so many centuries.

The newly-elected Corporation entered upon their duties with an enthusiasm which the extreme democrat may admire, the antiquarian regret. No doubt inspired with a desire to be thorough, the newly-elected governing body proceeded forthwith to dispose of all the Corporation plate and regalia. The gold mace was sold as a useless bauble. Their successors, during the decades which followed, have done their best to recover what their predecessors so hastily disposed of, and, by the public-spirited action of the citizens, much of it has since been restored. The mace, purchased during the Commonwealth in 1669 to replace one lost at the siege of the town in 1645, was repurchased from the then owners by subscription in 1866. A mayor's chain was acquired, and the serjeant's mace presented to the Corporation by a gentleman who purchased it at the time of the auction.

A citizen of a century ago would gaze with astonishment upon the city to-day. A country town of about 44,000 inhabitants in 1836, to-day Leicester embraces a population of approximately a quarter of a million, but to attempt an epitome of the doings, and to record the progress of one of our great industrial centres within the space at disposal, is not an easy task.

For many years there is little to relate of general interest. The gradual progress of the industries, the introduction of and improvement in machinery, particularly in the boot and shoe trades, the enterprise of their business men, and possibly their geographical position, and the nature of their industries all tended to convert the old country town into the large industrial centre we know as Leicester to-day.

Prompt advantage was taken of the powers conferred by the Sanitary Acts, and Leicester as a public health authority was early in the field, but it was not until the seventies, when the general trend was to absorb existing undertakings for the supply of gas and water, that we find Leicester enlarging her scope of control so as to include what are known as 'trading undertakings,' and it may be of interest to describe what the city's activities embrace at the present time.

Water Supply.

By the enterprise of a private company, Leicester received a supply of water for some years before the date when public authority controlled it, but as time progressed and the population increased, this supply became inadequate, and further efforts on behalf of the private undertaking were found to involve financial assistance by the city to enable their enterprise to be carried on. Eventually the city authorities decided to acquire the water undertaking, and contemporaneously to acquire the undertaking

carried on by a private company for the supply of gas for lighting purposes. The water undertaking in Leicester is to-day supplied from Thornton Reservoir, completed in 1854; Cropston Reservoir, completed in 1870; and Swithland Reservoir, completed in 1894. From these reservoirs the undertaking can obtain 6 million gallons per day, but it was realised many years ago that this supply was not sufficient to meet the ever-growing demand.

Eventually a bill was promoted in Parliament in 1899, upon the advice of the late Mr. John Breedon Everard, authorising the impounding of water from the Valley of the Derwent in Derbyshire. The cities of Nottingham and Sheffield and the borough of Derby at the same time considered they were entitled to a supply from this area, and the result was an arrangement whereby a joint board was established by an Act of Parliament passed in that year. The Derwent Valley Water Board to-day consists of representatives of the corporations of Leicester, Nottingham, Derby and Sheffield, and from this source Leicester (being the predominant partner) receives an average daily supply of approximately seven million gallons. The whole of the works authorised to be constructed have not yet been carried out, but when they are completed, the joint board will be enabled to supply an amount of water which will furnish to Leicester an average daily amount of 10½ million gallons.

The water obtained from the Derwent is excellent and, following upon filtration at Bamford (the southernmost point of the Derwent watersheds), the Leicester portion is delivered at Hallgates, some five miles out of the city. At Hallgates the water is subjected to mechanical pressure filtration, during which process it is decoloured and rendered alkaline. The first process renders the water suitable for drinking and manufacturing purposes, and the latter process is carried out as a prevention against plumbo-solvency and action upon iron pipes.

Gas and Electricity.

It has already been observed that the gas undertaking of the Corporation was acquired contemporaneously with the water undertaking. Originally operated by a private company, it has since 1878 formed part of the Corporation's activities. The undertaking has developed extensively in the course of years, and to-day supplies the city and a considerable area beyond with gas for power, industrial, and domestic purposes. There are two large works, one at Aylestone, where the plant established is of the Glover West vertical retort system, of a producing capacity of 10½ million cubic feet per day, together with carburetted water gas plant, capable of producing 6¼ million cubic feet per day. This includes the latest automatic plant of Messrs. Humphreys & Glasgow, capable of producing 2¼ million cubic feet per day. The second works, at Belgrave, is also equipped with Glover West vertical retort coal gas plant, of a producing capacity of 4 million cubic feet per day. The undertaking has been financially a great success, and the Corporation have always endeavoured to keep their plant in good condition and up to date.

Originally, the electricity supply by the city, under the powers of a Provisional Order obtained in 1891, formed part of the undertaking

carried on by the city's gas department. A small plant was established at Aylestone, and although current was taken for lighting purposes somewhat extensively in the centre of the city, it did not progress to any marked degree for some years. It was found to be not entirely suitable for power purposes.

In 1908 the Corporation, in order to meet the demand, promoted a Private Act, and obtained power to sell current from the plant operated by them for the purpose of supplying power to their tramways undertaking, and under this provision they were enabled to supply consumers by agreement for power purposes. Thereafter, we find the demand for current increasing to a very marked extent. Further plant was established from time to time, and eventually the undertaking was severed from the control of the gas department, and power obtained to build a new generating station.

In 1919 the Corporation acquired a large area of land known as the Freemen's Meadow, and, in pursuance of powers possessed by them, have erected on that site a very fine modern station. At Freemen's Meadow they have installed six units of 69,750 kilowatt capacity, generating upwards of 108 million units per annum, of which they dispose of approximately 86 millions. The rates for supply are low, and electricity, largely the prime mover in the city factories, is becoming more and more extensively used.

Tramways and Omnibuses.

In pursuance of their general policy to absorb all public utility undertakings, the Corporation acquired in 1902 the then existing tramways, and obtained powers by an Act of that year to operate them municipally. They at once proceeded to extend their route mileage, and to-day operate 178 tramway cars upon 23 miles of route. The undertaking has been maintained out of revenue, and is to-day probably one of the best services of its kind in the country.

In order to link up, and to meet the growing demands for transport, the Corporation further obtained powers in 1930 to operate a fleet of omnibuses. These, sixty-two in number, now serve most districts within the city.

Sewage Disposal.

Leicester is so situated that, except in the river valley, it is surrounded by rising country, and as a result the city has been put to considerable expense in dealing with its sewage. In common with other large cities, the proper drainage of the district and the sewage disposal have become an ever-increasing problem. This difficulty was somewhat accentuated in Leicester in consequence of the extensive pumping required.

The first works were constructed at the Abbey Meadow in about 1853. The sewage was then pumped into tanks, lime was mixed by means of agitators, and the effluent run off into the river. In 1877 ten acres of additional land were purchased, and additional tanks were constructed, but following a report by their then surveyor, the Beaumont Leys Farm was acquired, consisting in the aggregate of about 2,000 acres. The

scheme was completed in 1891, and consisted of a pumping station and 1½ miles of double 33-in. rising mains, sedimentation tanks, etc. In 1894 an 8-ft. diameter storm outfall culvert was constructed at a cost of £80,000, leading from the Abbey Pumping Station to Wanlip, about four miles away, with a discharging capacity of about 80 million gallons per day.

An increase in the population necessitated further works, and in about 1902 the sewage from the Belgrave district was, by increased pumping plant, dealt with at Beaumont Leys Farm. Further sedimentation tanks were constructed, and 12 acres of contact beds laid down. The sewage was treated in this manner until 1912, and, despite the fact that the main beam engines at the Abbey Pumping Station had been working night and day with efficiency for nearly forty years, the town had outgrown their pumping capacity, with the result that slight storms overflowed the weir discharging into Wanlip.

A scheme was prepared by the late City Surveyor, Mr. E. George Mawbey, in consultation with the late Mr. G. Midgley Taylor. It has already been observed that Leicester lies in a basin, and all sewage has consequently to be pumped 167 ft. to Beaumont Leys Farm for treatment. Belgrave Pumping Station raises the flow from that district, amounting to 660,000 gallons d.d.w.f. through a 15-in. pumping main to the old high-level works. The remaining d.d.w.f. flows to the Abbey Pumping Station, partly through three 5-ft. diameter cast-iron pipes passing under the river into the large bellmouth, and partly through the new 5 ft. 9 in. diameter western main outfall, the whole discharging into the new screening chamber. The flow enters the screening chamber by a new 16-ft. by 5-ft. reinforced concrete culvert, and is joined by the western main before referred to. The sewage is then screened by four electrically driven screens and raking apparatus. It then passes through four detritus tanks, 108 ft. long by 20 ft. wide, where heavy mineral matter is intercepted. The detritus is removed by an electrically driven travelling grab crane which runs along the outer walls of the tanks. The detritus is tipped on land which has been purchased by the Corporation for this purpose. The sewage flows continuously through these tanks over weirs at both inlet and outlet ends. At the latter three times the dry weather flow, amounting to 23 million gallons per day, flows direct to the pumps. The sewage in excess of the 23 million gallons flows over a weir 148 ft. long, through a reinforced concrete spillway to five underground storm water tanks, having a total capacity of 2½ million gallons. There are numerous other ancillary works, and the sewage system to-day in Leicester is proving very effective.

Open Spaces and Recreation Areas.

Leicester has long been known for its numerous open spaces, and approximetely one-tenth of its area is appropriated for this purpose.

The Victoria Park embraces an area of 69 acres. It is situated on the main road to London, and was for a number of years used as a race-course. The site forms part of the town's ancient estate, and is now appropriated for general use as an open space. It is in this park that Leicester's famous War Memorial, designed by Sir Edwin Lutyens in the form of

an Arch of Remembrance, is situated, and the gates at the entrances to London Road and Lancaster Road, the generous gift of Sir Jonathan North, were also designed by the same architect.

The Abbey Park, situated to the north-west of the city, embraces 57 acres. This park was constructed upon land reclaimed after Leicester's flood prevention scheme. Upon the opposite side of the stream stands Leicester Abbey, the gift to the city of Lord Dysart. Cardinal Wolsey was buried here, though the actual position is not known.

The Western Park, situated as its name implies on the western side of the city, is the largest open space possessed by the city. One hundred acres are appropriated as a park and for recreation, cricket, football, and tennis, and 84 acres for the purpose of an 18-hole golf course.

About a quarter of a mile away, another intersting addition to the Corporation's parks and open spaces has recently been acquired. The city purchased a few years ago a large estate of approximately 1,000 acres to enable them to proceed with their very extensive housing schemes. The park has been appropriated by the Corporation as an open space.

There are numerous other recreation grounds and open spaces, and it would not do to leave this feature of our city without a reference to Bradgate Park, which consists of some 1,000 acres, once the home of Lady Jane Grey. It was purchased by the late Mr. Charles Bennion and presented to the city and county. The freehold is vested in the city and county jointly, and is managed by a trust, upon which the city and county are represented, together with three donor's trustees. The park is maintained in its original condition, and forms one of the most attractive features of the county.

Roadway Development.

Leicester, in common with all other of the old English towns, has had to consider and, at very serious expense, endeavour to adapt itself to modern requirements. Many improvements of purely local importance have been effected from time to time by our ancestors, but the exigencies of modern traffic have forced us to consider town development upon a greater and more far-reaching scale.

Apart from an improvement in the High Street about thirty years ago, Leicester had made no serious attempt to widen her main thoroughfares until 1922, when a proposal was submitted for widening the main street from the Midland Station to the Clock Tower. This proposal, while relieving one of the most congested thoroughfares in the city, would have had to have been supplemented by some means by which the traffic could have passed on. It did not, however, gain local support and was abandoned.

Later, a scheme was submitted by the Corporation of a somewhat Napoleonic character. This scheme, prepared with great care, would, in effect, have immensely improved the internal communications in Leicester in the course of time, in addition to providing better means for dealing with through traffic. The scheme would have involved a gross expenditure, according to the estimates submitted, of approximately £3,830,000, and would have dealt with traffic east and west as well as

north and south. It was not intended to do otherwise than take parliamentary powers to acquire the requisite properties compulsorily, and the scheme would have been put in hand in sections as and when time proved practicable.

The proposal, however, met with severe opposition. There appeared to be a general impression that the huge expenditure involved would be incurred immediately, and was beyond the financial capabilities of the city. Without expressing any view as to whether this objection could have been sustained, it undoubtedly would have made Leicester, in days to come, a vastly different town from what it is at the present time. However, the proposal was not approved, and in consequence, in the year 1924, the Corporation submitted a modified scheme which involved the construction of a new street passing from the London road immediately below the present Midland Station and going straight across the Humberstone Gate to the Old Cross, Belgrave, and by the widening of Belgrave to the Great Northern Station, achieving a wide and direct thoroughfare north and south. Certain connecting approaches were also embraced.

The proposal was submitted to Parliament and duly sanctioned. The estimated expenditure for the execution of the necessary street works and the acquisition of the lands was £1,111,000.

Parliament considered the work so essential for traffic purposes, that the Corporation were placed under an obligation not only to acquire the lands, but to construct the works within ten years from the passing of the Act. The actual street construction has been carried out, and through communication has been effected, the new road being 85 ft. wide.

This internal improvement, the largest ever undertaken by the city of Leicester, and one of the largest undertaken by any of the great towns, is undoubtedly proving an immense traffic convenience.

Judicial Courts.

The city of Leicester has long had its separate Commission of Assize, and although prior to the Reformed Corporations Act, Leicester had long possessed a Recorder, it was granted a separate Court of Quarter Sessions in 1836 and a separate Commission of the Peace in the same year.

The Diocese of Leicester.

Leicester was a diocese in the year 680, consequent upon the division of the diocese of Mercia, but ceased to be a diocese in 870, following the Danish Invasion. In 1072 it became part of the then newly established diocese of Lincoln, and in that diocese it remained for more than 750 years, until it was transferred to the diocese of Peterborough in 1839. It was separated from the diocese of Peterborough in 1927, and now forms the centre of the diocese of Leicester.

Civic Status and City Arms.

Leicester, as we have seen, was a city so far back as 200 years before the Norman Conquest, but lost its civic status in the manner already related.

In the year 1919 their present Majesties King George and Queen Mary officially visited the city, and in commemoration of that occasion by Royal Warrant restored to the city their civic title, and in 1928 by Royal Warrant the title of Lord Mayor was conferred upon its Chief Magistrate.

Leicester is proud of its ancient history, and it may be fitting to conclude with a short description of the Arms of the City.

The Arms of the City of Leicester are held by prescription and not by grant, and date back earlier than the College of Heralds itself. The circumstances attending the user of portions of the Arms are lost in the mysteries of the past. The cinquefoil, forming the centre-piece, probably takes its origin from the following circumstances.

After the Conquest, the Norman earls controlled the small centres of population, which then constituted the boroughs, and the townsmen were the earl's men who followed him, each using the device effected by their respective lords. The cinquefoil was the device adopted by Robert de Beaumont, first Earl of Leicester, and used by Fitz Parnel, one of his successors. It was commonly used and adopted at that time by the burgesses as their device. Its origin is uncertain.

The Wyvern, which appears as the crest upon the helmet, is derived from Thomas, Earl of Lancaster and Leicester. It appears upon his seal in 1301. It is described in Boutell's *English Heraldry Book* as ' a fabulous creature, being a species of dragon with two legs and represented with its tail nowed, that is to say, coiled in a knot as a snake.' It would appear probable, that the Wyvern was used by the men of Leicester from the earliest times. It is recorded in the early days of the Wars of the Roses, that the followers of each lord were led to the field under distinctive banners, which were emblazoned with well-known crests or heraldic emblems. The townsmen played a conspicuous part in the battle of Towton Moor on the Yorkists' side, and it is recorded that they met under their various banners : the Black Ram of Coventry, the Ship of Bristol, the Dragon of Gloucester and the Griffin of Leicester. The Griffin is the Wyvern referred to.

The Arms of the City were confirmed in 1681, in the reign of Charles II, and upon the charter already referred to, granted by his present Majesty, restoring the title of the civic dignity to the city, the College of Heralds granted supporters—' on either side a lion reguardant Gules gorged with a Ducal Coronet suspended therefrom by a Chain or a Cinquefoil ermine pierced Gules.'

IX.

EDUCATION IN LEICESTER

BY

F. P. ARMITAGE, C.B.E., M.A.,

DIRECTOR OF EDUCATION.

Early History—Thomas Wyggeston—Collegiate School—Technical Classes—College of Art and Technology—School of Cookery—Wyggeston Boys' and Girls' Schools and Alderman Newton's—Mary Royce's Night Classes—Canon Vaughan and the Vaughan Working Men's College—Adult School Union—Workers' Educational Association—Leicester Education Authority and the 1918 Act—Schools Grouping Scheme—Provision of Playing Field Facilities—'Experimental' School—Special Schools—Medical Inspection—After-school Employment—Additional Secondary Schools—Growth of the Colleges of Art and Technology—Founding of the University College—Vaughan College becomes the Extra-mural Department of the University College.

In the sixteenth century Thomas Wyggeston founded a free school in High Cross Street, and for 150 years there was no other place of public education in the town. Then, in 1708, a school was built in East Bond Street by members of the Great Meeting. In 1761 Alderman Newton founded his Green Coat School; St. Mary's, the first parochial school, was built in 1783; St. Martin's in 1790, St. Margaret's in 1807. The County National School, built by subscription in 1814 on a piece of land provided by the Crown, was intended to be a central model school for town and county; here young masters received their first lesson in the art of teaching. The population of Leicester was then 24,000.

Between 1814 and 1870 more schools were built by the Established and Free Churches and by the Roman Catholics. Private enterprise provided the Collegiate School—at first a private secondary school for boys, among whom was Wallace the naturalist—and the Proprietory School, the buildings of which were taken over by the Corporation for the purposes of a museum in 1848.

By 1870 Leicester's population had grown to 96,000. In the various schools in the town providing an elementary school education there were 10,053 pupils; the accommodation required under the 1870 Education Act was 17,903. During the next five years eight schools were built accommodating over 7,000 children.

At this time the leaving age was 13, but total exemption could be attained at the age of 10. The percentage of attendance was sometimes as low as 70. By 1892 it was 81—but 818 cases were heard by the magistrates. To-day the percentage of attendance is almost 90, and scarcely a case ever comes before the magistrates. In 1892 there were 1,588 half-timers on the school rolls—two years later there were none.

Meanwhile special instruction had been provided for the mentally deficient, the blind and the deaf, and a school at Desford opened for children committed by the magistrates.

For many years a Committee working under the influence of the Leicester Chamber of Commerce was responsible for technical classes in hosiery and boot and shoe manufacture; these were held at the Wyggeston Boys' School (now the Alderman Newton's) and in the old Mercury Office, 21 St. Martin's. Moreover, since 1870, a private society had maintained a School of Art.

In the early nineties a Technical and Art Schools Committee of the Corporation was formed; the first wing of the College of Art and Technology was opened in 1897.

In 1877 the Leicester and Leicestershire School of Cookery was established in No. 21 St. Martin's. From 1890 to 1907, before it was taken over by the Education Committee, it was known as the North Midland School of Cookery.

When the Education Act of 1902 came into force there were three secondary schools in the borough—the Wyggeston Boys' and Girls' Schools and the Alderman Newton's. The former came under the Education Authority in 1909, the latter in 1910. In 1908 what had been a pupil teachers' centre was converted into a dual secondary school, the Newarke School.

During the second half of the nineteenth century private effort had done much to put the tools of knowledge within reach of the illiterate. Mary Royce chose to teach boys when the Sunday school was opened in Sanvey Gate in 1868. Soon she was teaching the three R's, chemistry and French to week-night classes, then taking her pupils for holiday rambles. Ultimately she built the Royce Institute in South Church Gate.

The Rev. Daniel James Vaughan was Vicar of St. Martin's. Following the example of his friend F. D. Maurice, who founded the London Working Men's College, he opened, in 1862, the Working Men's Institute in Union Street. This institute became known as the Working Men's College, and when Canon Vaughan died in 1905 there were over 2,000 students on the rolls. In 1908 the Vaughan Working Men's College and Institute in Great Central Street was opened by Sir Oliver Lodge.

In 1822 Thomas Cooper, the Chartist, started an adult school 'for the poor and utterly uneducated.' Other schools gradually came into being in town and county, and in 1889 the Leicestershire Adult School Union was formed.

In 1908 a branch of the Workers' Educational Association was formed in Leicester.

The passage of the 1918 Education Act almost coincided with the end of the war and the consequent return of teachers from military service. All was ready for an advance. The first thing done was to institute a general examination for all children between 11 and 12 who were competent to get a fair percentage of marks. This threw on the Authority the responsibility of pointing the way to secondary schools to

qualified children. The examination revealed the extraordinary difference in attainment of children of the same age in the elementary schools.

In accordance with the new Act, the Leicester Education Authority—like other Authorities,—prepared a scheme to cover the developments proposed for the next ten years. The core of their scheme lay in grouping the schools in the several areas of the town. This grouping allowed the bringing into certain schools of sufficient children over 11 to allow at least duplication of classes (boys and girls separately) for those of approximately the same year of age, the schools from which they were transferred becoming Junior Schools with a similar duplication of classes. Moreover, it was found possible to reserve one school in an area for children who had qualified for a secondary education but whose parents for one reason or another could not permit them to go to the secondary school. In these intermediate schools children were to follow a curriculum similar to the conventional secondary school curriculum, that they might easily be transferred to secondary schools should their parents on second or third thoughts wish this.

The Geddes axe came down upon many of the proposals made under the 1918 Act, but that portion of the Leicester scheme which affected ' grouping ' was put into operation, area by area, till in 1929 all the Council schools and most of the non-provided schools were reorganised.

Meanwhile the Hadow Report in 1926 gave national recognition of the principle on which Leicester had worked since 1921.

About the same time that the Authority began to reorganise their schools they began to provide playing-field facilities for the senior children. To-day every child over 11 has one organised game per week on the 87 acres owned or rented by the Authority, or on the parks and recreation grounds.

As one result of the duplication and triplication of classes and the consequent modification of curricula to suit different categories of intellect and interest it has been found possible to reduce the number of those transferred to special schools. On the other hand, it became very apparent that there was need for a school of a special type to deal with cases of special disability as to reading, writing, behaviour, etc. The Committee, therefore, opened an ' experimental ' school at Haddenham Road, where such problem cases could spend 3, 6, 9 months, 1 year, 2 years, as the case might be, until the disabilities were removed and the children could return to the normal schools.

Infant departments were unaffected by grouping, but, during the last five years, nursery classes to the number of 23 have been provided where children between 3 and 5 can be educated as in nursery schools in good social habits.

The school for the deaf and semi-blind is accommodated in a mansion situated in beautiful grounds in Stoneygate. A new school for the mentally deficient has recently been built. The much larger premises hitherto occupied by them—also a mansion in extensive grounds,—have been appropriated by the experimental school.

The Leicester Education Authority have made very complete provision for the medical inspection and treatment of children in the elementary

and secondary schools. Every child in the former is inspected three times during school life. There are three dental clinics, an eye clinic, an operative clinic with twelve beds for tonsils, adenoids and mastoids and an operative clinic for crippling. For many years X-ray treatment has been provided. It is worth noting perhaps that the records of school medical officers show that since 1902 there has been an average increase in height of the Leicester boys of 1 in., girls, 1½ in., and an average increase in weight of boys by 6 lb., girls 8 lb.

During the last term of an elementary school child's life he is visited at the schools by the Committee's employment officers and advised as to the vacancies that have been notified by employers, and his own qualification for filling them. At the age of 16, when he becomes eligible for unemployment benefit, he must attend an evening institute as a condition of getting this benefit.

It has been stated already that one result of the general examination was to show the extraordinary diversity of academic attainment among elementary school children—it also showed how many there were qualified to profit by the conventional type of secondary education in comparison with the number of places in secondary schools available. The Education Committee, in 1919, immediately took steps to remedy this—the provision of intermediate schools has been referred to above,—by providing a Secondary Boys' School and two Secondary Girls' Schools, one (the Collegiate) by purchase from a private owner. There were then 3,500 places available. But the Committee were not satisfied that the conventional secondary curriculum was adapted to provide a right form of secondary education for all of ability to profit by staying at school till at least 16. In consequence they opened a new type of school—the Gateway School for Boys,—in which those of marked ability but with no special interest in academical subjects could be educated till 16 years of age at least. They built, moreover, a 'Gateway School' for Girls in the Newarke, but for reasons of economy transferred the Newarke Girls' School there and used the old Newarke School buildings in part for administrative offices.

But it was not only in respect of full-time education that the post-war enthusiasm displayed itself; each year the number of those attending the evening schools, particularly students over 18, increased. The evening classes at the Technical and Art School—now the Colleges of Art and Technology,—grew till they more than filled the premises of a large Secondary School as well as that of the College which had already been increased by an additional wing in 1898. It was necessary to add another wing, and even then the premises were not big enough—the completion of the building is only held over until the present straightened circumstances are passed.

The 1918 Act made it incumbent on the Authority to make such provision that no boy or girl should be deprived of any form of education by which he or she could profit. There was no University or University College in the immediate neighbourhood: Leicester set out immediately to develop one of her own. The University College was registered as a company in 1921; a site had been presented and a considerable

endowment fund provided. To-day there are 94 full-time and 116 part-time students on the College rolls.

It should be noted that during the year 1931–32, from the city alone, 119 secondary school pupils obtained exemption from the London Matriculation and 21 passed the Intermediate Examination for the B.A. Degree.

Since its opening the Vaughan College has been the centre of education conducted in the spirit of its founder. In 1930 the Board of Governors handed the buildings and endowment over to the University College as a home for the extra-mural classes conducted under the latter's ægis. The development of extra-mural work has been in consequence very rapid. Half the building was let to the Education Committee for the holding of adult classes in connection with the Evening Institutes. This adult Vaughan Institute has proved extraordinarily popular.

In connection with the great developments referred to above, one name must be mentioned, that of Alderman Sir Jonathan North, D.L., J.P., who for 26 years has been chairman of the Education Committee, and (from its earliest days) chairman of the University College Council.

It is believed that in very deed the way to the top by any recognised route is open to every Leicester child. By free places, maintenance allowances, scholarships, and loans the travelling along this route is made possible to the poorest.

X.

MEN OF SCIENCE IN LEICESTER AND LEICESTERSHIRE

BY

F. B. LOTT, M.A.

Individual Scientists in Early Days—William Lilly, 1602–1681—William Ludlam, 1717–1788—Robert Bakewell, 1725–1795—Richard Pulteney, 1732–1814—Richard Phillips, 1767–1840—Henry Walter Bates, 1825–1892—The Scientific Sections of the Leicester Literary and Scientific Society—Geology, Botany, Zoology, Meteorology, Chemistry and Physics, Entomology, Economics, and Astronomy—The Leicester Museum, 1849–1914—Brief Sketch of more Recent Changes and of Present Conditions.

This chapter gives a short account of men born in, or connected with' Leicestershire who did notable work in science.

The first of these is that of one widely known and important in his lifetime—William Lilly (1602–1681). He was born at Diseworth and educated at the Grammar School, Ashby-de-la-Zouch. Early in his life

he went to London, and there he was a very successful practitioner in astrology—not without some mixture of medicine and politics. He wrote his autobiography. He occupies more than eight columns in the *Dictionary of National Biography*.

The next name is that of the Rev. William LUDLAM (1717–1788), mathematician. He was the son of Richard Ludlam, M.B. Cambridge, who practised in Leicester. He went from Leicester Grammar School to Cambridge and became a Fellow of St. John's College. In 1749 he was Vicar of Norton-by-Galby, Leicestershire. In 1768 he had the living of Cockfield in Suffolk. He then gave up his fellowship and came to live with his brother Thomas, who was Confrater of the Wyggeston Hospital in Leicester. In 1772 he married, but he lived on in Leicester till his death in 1788. During these last twenty years of his life he wrote most of his works. His *Rudiments of Mathematics* (1785) 'became a standard Cambridge text-book, it passed through several editions and was still in vogue in 1815.' Six other mathematical publications are named in the *Dictionary of National Biography*. An essay of his on Newton's Second Law of Motion, for which he proposed to substitute something of his own, was rejected by the Royal Society. The Society accepted papers by him on mechanics and on astronomy.

Robert BAKEWELL (1725–1795), the son of a farmer, was born at Dishley. He succeeded his father in the farm and became one of the most successful and perhaps the most renowned of scientific agriculturists. His fame rested on his great success in improving the breed of sheep. He developed a breed known as 'Leicesters,' with long lustrous wool. This was of importance not only to the manufacturers of hosiery in Leicestershire; the 'Leicesters' were prized in other counties, and were for many years known in France as 'Dishleys.' Bakewell also improved the breed of cattle. He was successful in irrigating grassland and in all details of farm management.

'Many of the present humane notions regarding animals were anticipated by Bakewell, his stock being treated with marked kindness, his sheep being kept "clean as race-horses, and sometimes put into body clothes," and even his bulls were remarkable for obedience and docility" (Quotation in the *D.N.B.* from Throsby's *Views in Leicestershire*).

Joseph PAGET (1700–1789) and Thomas PAGET (1732–1814), of Ibstock, were friends of Bakewell of Dishley. They worked on the same lines, being pioneers of land drainage and of cattle and sheep breeding. Later Pagets were eminent in Leicester as surgeons and as bankers. One of the family, John Paget (1808–1892 see *D.N.B.*), having married a Hungarian lady, introduced scientific agriculture in Hungary. He wrote a book on *Hungary and Transylvania*.

Richard PULTENEY (1730–1801), physician and botanist, was born at Loughborough. His father, Samuel Pulteney, was a tailor who had some landed property, which passed to his son Richard. Richard Pulteney, after being apprenticed to an apothecary, went to Leicester and was for some years in practice there, with little success. He had, however, begun

to write on botany in the *Gentleman's Magazine*, and had sent some papers to the Royal Society. His mind had been guided to botany by an uncle, his mother's brother.

In 1764 he went to Edinburgh to get the degree of M.D. He got it without spending time in residence. In the same year he went to London and was introduced to William Pulteney, who in 1742 had been made Earl of Bath. The Earl recognised him as a kinsman and made him his own physician. Very soon the Earl died. Dr. Pulteney then went to Blandford in Dorset. He quickly made a fortune by a very widely spread practice. He devoted his leisure to botany and conchology. His most important works were *A General View of the Writings of Linnæus* (1781), and *Historical and Biographical Sketches of the Progress of Botany in England* (1790). Among his minor writings was ' A Catalogue of rare Plants found in the Neighbourhood of Leicester, Loughborough, and Charley Forest.' This was contributed to Nichols's great book on Leicestershire.

Richard PHILLIPS (1767–1840) came to Leicester and opened a commercial academy in 1788. He is not eminent as a man of science, but he did, in conjunction with William Gardiner, Leicester's most famous amateur musician, found a society for scientific investigation. It was called ' The Adelphi.' A number of young men joined it. It was, so far as the compiler of these notes can ascertain, the first attempt in Leicester to initiate the co-operative scientific study of a society, as distinguished from the studies of individual persons. The society had a short life. It was suspected of sympathy with the French Revolution and soon suppressed by the Town Authority. In 1790 Richard Phillips opened a shop for books and medicines. He was imprisoned for eighteen months for selling *The Rights of Man* by Tom Paine. In 1796 he went to London. He became a remarkably successful publisher of educational and scientific books. In 1807 he was Sheriff of London. In 1808 he was knighted by George III. Sir Richard Phillips lived till 1840.[1]

In 1845–46 a friendship began in Leicester between two young men who both afterwards became famous. Henry Walter BATES (1825–1892), a native of Leicester, and Alfred Russel WALLACE (1823–1913), who was at that time an assistant master in the Collegiate School.[2] H. W. Bates, after some education at Creaton's boarding school at Billesdon, had been apprenticed to a hosier, his duties comprising opening and sweeping up the warehouse between seven and eight in the morning. Subsequently he worked as a clerk. ' His scanty leisure he devoted to self-improvement at the liberally managed Mechanics' Institute. His holidays when possible were spent in scouring Charnwood Forest with his brothers ; for he was already an enthusiastic entomologist and collector. His first contribution to entomological literature was a short paper on ' Coleopterous

[1] *An Old Leicester Bookseller*, by F. S. Herne.

[2] The first headmaster of the Collegiate School was William Thompson, then Fellow and afterwards Master of Trinity College, Cambridge. J. F. Hollings was a master and F. T. Mott a scholar at the Proprietary School. (They will be mentioned later.) (*Leicester Memoirs*, by C. J. Billson.)

Insects frequenting Damp Places,' dated Queen Street, 3 Jan., 1843, and printed in the first number of the *Zoologist*.

A. R. Wallace had taken up botany and started an herbarium in 1840. They joined in the study of entomology and they both read Malthus on Population and Darwin's *Journal of a Naturalist*. In 1848 they went together to the Amazons. Bates spent eleven years there, and in 1863 published *The Naturalist on the Amazons*, having been urged to publish the book by Charles Darwin. In 1864 he became assistant-secretary to the Royal Geographical Society : ' a post which, to the inestimable gain of the Society, and to the advantage of a succession of explorers, to whom he was alike Nestor and Mentor, he retained till his death ' (*Encyclopædia Britannica*, Article ' Bates, Henry Walter ').

Leicester Literary and Philosophical Society.

So far these notes have been about men whose scientific studies were personal and shared, if shared at all, only by kinsfolk or private friends.[3] In the last quarter of the eighteenth century and in the first half of the nineteenth many local societies for co-operation in studies were formed. This movement was checked and suspended during part of that period by the shock of the French Revolution, by the long war which followed it, and by the bitter party spirit which prevailed after the war.

Among the earliest of these societies was the Manchester Literary and Philosophical Society. It was founded in 1781. It lived through the troublous years. In 1835 George Shaw, M.D., who had been a member of the Manchester Society before he came thence to Leicester, and his friend, Mr. Alfred Paget, were the prime movers in the foundation of the Leicester Literary and Philosophical Society.[4] In 1837–38 this Society began to collect a museum. The collection rapidly increased. In 1849 it was presented to the town, formally accepted by the Mayor at a large gathering, and housed in the building (which a few years before had been built for the Proprietary School) purchased by the Town Council for what thus became the Town Museum.

The Society had formed committees of its members to manage departments of its Museum before presenting it to the town. For a long time the connection between the Museum Committee of the Town Council and the Council of the Society continued to be very close indeed, the same persons being in many cases members of both. There can be little if any doubt that the ' Sectional Committees ' of the Society for the study of particular branches of Science, afterwards called simply the ' Sections,' originated from the committees appointed for ' departments ' of the Museum before it became the Town Museum. In the

[3] Some more of the early botanists, especially the Rev. W. H. Coleman and the Rev. A. Bloxam, whose works were used by the editors of *The Flora of Leicestershire* will be mentioned later.

[4] Prof. Sedgwick, at a dinner given to him in Leicester in October 1837, said : ' The additions made to the great stream of knowledge by societies formed in provincial towns were rich and copious. Manchester, from a period when it was not more extensive than Leicester, had taken the lead. Cambridge and Newcastle, York and Bristol, were following that bright example, he trusted that Leicester would soon distinguish itself in the same noble course.'

course of years the relations between the Society and the Museum have greatly changed, but up to the present time much of the most valuable work of the Society, that of its Sections, has been done in close connection with the Museum, not a little of it by officers of the Museum. The following pages will tell of the subjects studied by the Sections and indicate the shares in the work of some of the chief workers.

Geology was taken up by the Society before the Sections were definitely constituted in 1849. In March 1837 the Rev. Andrew Irvine, B.D., F.G.S., in his Presidential Address, suggested that a Natural History Museum should be formed, and said that he would willingly present to it his own collection of specimens, mineralogical and geological. The first honorary members of the Society were the Rev. William Buckland, D.D., F.G.S., and the Rev. Adam Sedgwick, B.D., F.G.S., pioneers of geology in Oxford and Cambridge. The latter spoke about the geology of Charnwood Forest at a dinner given to him at the Three Crowns on October 6, 1837.

The two members of the Society, who in these early days read most papers on geology, were Mr. John Laurance,[5] who left Leicester and became an honorary member in 1842, and Mr. James Plant, F.G.S. The latter also spoke on geology at the Society's excursions. On March 28, 1870, he lectured on 'Geological Formations of the County as illustrated by the Column of Rocks in the Museum Grounds.' He had constructed this column in order to preserve in a permanent and educational form a large number of specimens liberally supplied by the owners of quarries throughout the county for exhibition at the meeting of the Royal Agricultural and Royal Horticultural Societies at Leicester in 1868. The column was removed when the Museum building was enlarged in 1877. It was an imitation on a small scale of a huge column at the Great Exhibition of 1851, and of others at the Crystal Palace.[6] The late Dr. F. W. Bennett remembered seeing it.

The section of the Society for Geology decreased in numbers during the eighties, and though there were a few who were diligent in the study hardly any papers were read, and the meetings dwindled away. The Council in their Report in 1889 'regret that Section C (Geology) has been obliged to follow the example of Section B (Astronomy, Physics and Chemistry), and ask the Council to terminate its existence. They have however made arrangements for the amalgamation of Section C with Section E (Zoology), so that the opportunity for organised study of

[5] John Laurance was the author of a book entitled *Geology in 1835: A popular sketch of the Progress, Leading Features, and latest Discoveries of this rising Science.* The first sentence of the preface is: 'The attempt to compress so vast a theme as Geology within the narrow limits of a duodecimo volume of such spare dimensions will be regarded by those, who in ponderous *tomes* have communicated to the world the results of years of labour in this department of science, as absurd and futile.'

The book was published by Simpkin and Marshall in London, 1835, but printed by Cockshaw in Leicester. Geology was then a rising science. The Geological Society of London was founded in 1807. The *Oxford Dictionary* gives 1795 for the first quotation of the word in the modern sense. For many geological words later dates, e.g. 'Cambrian,' 1836.

[6] *Leicester Chronicle*, April 2, 1870.

Geology may not be lost.' The records in the *Transactions* of Section E show that the study was maintained.[7]

On January 16, 1899, while Geology was still amalgamated with Zoology, Dr. Frederick William Bennett, M.D., gave an account of 'The Rocks of Charnwood Forest.' It was the first time in which his name appears in the *Transactions*. The opening is thus recorded: 'During 1898 I studied the detailed descriptions of the Charnwood Forest Rocks given by Mr. Hill and Professor Bonney and obtained a large number of specimens of the rocks. I have arranged about 300 of these on a rough map of the district so that comparison can easily be made between the rocks of different parts.'

In 1899 those who were especially interested in geology petitioned the Council 'in view of the increased interest in the subject to reconstitute Section C.' This was done. The reconstituted Section had for its chairman, Hermann Alfred Roechling, C.E., F.G.S., whose professional address was 'The Office of the Borough Surveyor,' and for its vice-chairman, Mr. Louis B. M. Hodges, the Headmaster of St. Martin's School. Mr. C. Fox Strangways, of H.M. Geological Survey, was a most valuable member. The first paper on May 4, 1899, was by Mr. Hodges—'Suggestions for working a Geological Section.' In the first session there were seventy-nine members. There were twelve evening meetings, including a conversazione, and six summer excursions, four of which were conducted by Mr. C. Fox Strangways. The activity of the Section was suspended during the war. It was very active before the war, and it has been so since the war, under the leadership of the late Dr. F. W. Bennett, who devoted the bulk of his spare time to the study of, and possibly possessed an unrivalled knowledge of, the rocks of the Charnwood Forest.

List of Geological Papers.

Mr. H. H. Gregory, M.A., the Honorary Secretary of the Geological Section, has supplied the following bibliography of the works of members of the Section. He has pointed out that it does not contain many valuable addresses, especially those by leaders of excursions, of which there are scanty records in the Minutes of the Section.

Bibliography of the Works of Members of the Geological Section of the Literary and Philosophical Society.

1. Plant, J.: 'Are the (Slate) Rocks of Charnwood Forest Laurentian?' *Geol. Mag.*, 1865.
2. Plant, J.: 'Geology of Leicestershire,' *Leicester Lit. & Phil. Soc.*, 1874–75.

[7] At this period the *Transactions* were printed at great length. 'A Contribution to the History of the Geology of the Borough of Leicester,' by Montagu Browne, F.G.S., F.Z.S., Curator of the Museum and Art Gallery, read before Section E, begins with p. 123, and ends, with half a page of thanks to the many who had helped him and to the Society for the publication, on p. 240. There are illustrations and diagrams.

3. Harrison, W. J.: 'The Syenites of South Leicestershire,' *Mid. Nat.*, 1880, also 1884.

4. Bennett, Dr. F. W.: 'The Charnwood Forest Rocks,' *Trans. Leic. Lit. & Phil. Soc.*, 1903.

5. Bennett, Dr. F. W.: 'The Buck Hill Grit,' *ibid.*

6. Stracey, Dr. B., and Bennett, Dr. F. W.: 'The Felsitic Agglomerate of the Charnwood Forest,' Part I, *ibid.*

7. Stracey, Dr. B.: 'The North-west of Charnwood,' *Trans. Lit. & Phil. Soc.*, 1906.

8. Keay, W., and Gimson, M.: 'The relation of the Keuper Marl to the Charnian Rocks at Bardon Hill,' *ibid.*, 1907.

9. Stracey, Dr. B., and Bennett, Dr. F. W.: 'The Felsitic Agglomerate of the Charnwood Forest,' Part II, *ibid.*, 1907.

10. Horwood, A. R.: Vol. xii, Part ii, *The Fossil Flora of the Leicestershire and South Derbyshire Coalfield, and its bearing on the age of the Coal Measures*, 81–181.

11. Bosworth, T. O., B.A., B.Sc.: *The Keuper Marls around Charnwood Forest.* (Published by Leicester Lit. & Phil. Soc., 1911.)

12. Bennett, Dr., Stracey, Dr., Bosworth, T. O.: 'Excursion to Charnwood Forest,' *Proc. Geol. Assoc.*, xxii, 24, 1911.

13. Bennett, Dr., and Stracey, Dr.: 'Excursion to Charnwood Forest,' *ibid.*, xxii, 205, 1911.

14. Bennett, Dr., and Lowe, E. E., B.Sc.: 'Excursion to Mountsorrel,' *ibid.*, xxiii, 257, 1912.

15. Bennett, Dr. F. W.: 'Note on Morley Hill,' *Trans. Leic. Lit. & Phil. Soc.*, 67, 1922.

16. Bennett, Dr. F. W.: 'The So-called Junctions at Bardon Hill,' *Trans. Leic. Lit. & Phil. Soc.*, 1923.

17. Bennett, Dr. F. W.: 'Age of the Charnwood Rocks,' *Trans. Leic. Lit. & Phil. Soc.*, 1925.

18. Lowe, E. E., Ph.D., B.Sc.: *Igneous Rocks of the Mountsorrel District.* (Published by Leic. Lit. & Phil. Soc., 1926, price 6*s.* 6*d.*).

19. Jones, F., M.Sc., F.G.S.: 'The Petrology and Structure of the Charnian Rocks of Bardon Hill,' *Geol. Mag.*, xviii, 1926.

20. Jones, F., M.Sc., F.G.S.: 'Preliminary Inquiry into direction of Joints, Faults, etc., at Groby,' *Trans. Leic. Lit. & Phil. Soc.*, 1926.

21. Jones, F., M.Sc., F.G.S.: 'A Structural Study of Charnian Rocks and Associated Igneous Intrusions,' *ibid.*, xxviii, 24, 1927.

22. Gregory, H. H.: 'Swanimote Rock,' vol. xxix, *Geology of Charnwood Forest, Trans. Leic. Lit. & Phil. Soc.*, 15–20, 1927–28.

23. Bennett, F. W., Lowe, E. E., Gregory, H. H., Jones, F.: vol. xxxix, *Geology of Charnwood Forest, Proc. Geol. Assoc.*, 241–298, 1928.

24. Bennett, F. W.: 'Remarkable Features in the Ulverscroft Valley,' vol. xxx, *Geology of Charnwood Forest, Trans. Leic. Lit. & Phil. Soc.*, 40–45, 1928–29.

25. Lowe, E. E., Stracey, B., Gregory, H. H.: *Ibid.*, vol. xxxii, *Geology of Charnwood Forest*, 26–34.

26. Stacey, B.: 'On Some Swiss Glaciers,' *ibid.*, vol. xxxii, p. 45.

What is to be said of the botanists of Leicestershire may be introduced by referring to the title-page and the preface of *The Flora of Leicestershire*. This is the title-page :—

THE FLORA OF LEICESTERSHIRE

INCLUDING THE

CRYPTOGRAMS

WITH MAPS OF THE COUNTY

ISSUED BY THE LEICESTER LITERARY AND PHILOSOPHICAL SOCIETY

COMPILED BY THE FOLLOWING SUB-COMMITTEE OF THE SOCIETY'S BIOLOGICAL SECTION : [8]

F. T. MOTT, F.R.G.S. THOMAS CARTER, LL.B.
E. F. COOPER, F.L.S. J. E. M. FINCH, M.D.
C. W. COOPER, M.B.

On the basis of a manuscript prepared in 1852 by the late Rev. W. W. COLEMAN, which has been enlarged, completed, brought up to date, mostly rewritten and entirely rearranged in accordance with the third edition of HOOKER'S ' STUDENT'S FLORA.'

WILLIAMS AND NORGATE
1886

In the preface it is stated that the only published Flora of Leicestershire was that of Miss Mary Kirby,[9] published in 1850 ; and that in 1875 Edwin Brown, Esq., of Burton-on-Trent, placed the manuscript of his friend the Rev. W. H. Coleman ' at our disposal.' The manuscript was dated 1852 and was almost ready for publication. Mr. Brown had stipulated that if it were published Mr. Coleman's name should be on the title-page.

The preface goes on to say that there had been great changes in Botany since 1852, and that more modern Flora had been published, that of Plymouth by T. R. Archer Briggs, and that of Hampshire by F. Townsend. Coleman had omitted nativity and habitat.

Three periods of botany in Leicester are then distinguished. The first was before 1820. Its authorities were Richard Pulteney, George Crabbe,[10] and Dr. Arnold, a physician in Leicester. The second period of botany in Leicestershire was 1820–1850 A.D. Its authorities were the

[8] At that time Section D was for ' Biology (Zoology and Botany).' Afterwards it was for Botany only.

[9] Miss Mary Kirby (Mrs. Gregg) and her sister Elizabeth Kirby wrote many story-books for children. She also wrote a very interesting book, *Leaflets of my Life*. She had many botanical correspondents, including the Rev. W. H. Coleman and the Rev. A. Bloxam.

[10] See above, p. 85, for Richard Pulteney. George Crabbe, the poet, had made a catalogue of plants in the vicinity of Belvoir.

Rev. W. H. Coleman [11] and Miss Kirby (already mentioned), the Rev. Churchill Babington, D.D., Fellow of St. John's College and Professor of Archæology, Cambridge, and the Rev. Andrew Bloxam of Twycross and Harborough Magna, near Rugby. He had been the naturalist on board the frigate *Blonde*, in the Pacific Ocean in 1824–25. He was Coleman's chief colleague and he prepared the list of plants for T. R. Potters' book on Charnwood Forest.[12] Others mentioned are the Rev. Charles Cardale Babington, Professor of Botany, Cambridge; James Harley, a well-known local naturalist; James Francis Hollings; the late Rev. R. W. McCall, F. T. Mott; and John Plant.

The editors of the Flora stated that they owed the chapter on 'Algæ' to Mr. Frederick Bates, a brother of 'Bates of the Amazon,' and that they had adopted, with some alterations, the chapter on 'Geography and Hydrography' from the manuscript of the late Rev. W. H. Coleman.

Mr. Frederick Bates is also named in a comparatively long list of those who helped the editors in their third period from 1850 to 1886. In writing of this period the editors were to a great extent writing of the work of themselves and of their contemporaries. One of them, Frederick Thompson Mott, is remarkable in many ways in the history of the Society. He was its President twice: in the sessions 1874–75 and 1890–91. He was chairman of the Section then named 'Natural History,' and later 'Biology,' from 1879–80 to 1895–96, except for two sessions, 1891–92, in which the Rev. T. A. Preston was chairman, and 1892–93, in which Mr. Thomas Carter was chairman. Mr. Mott's subjects were generally botanical or zoological; but sometimes literature, art, or philosophy. In March 1878, in a lecture to the Society entitled 'A Modern Theory of the Universe,' he 'proceeded to lay before his audience the outline of a theory which, he contended, preserved all the old truth, while at the same time it cast off all the worn-out garments, and added a great deal that was necessary to bring it up to date.' . . . It might seem to those who had been accustomed to regard matter as a real and substantial thing, and energy as something altogether different, that this theory which made active energy the only substance in the universe was a mere dreamer's speculation, but they must remember that it was little more than a modern development of the conclusions of such well-known thinkers as Plato, Descartes, Spinoza, and Bishop Berkeley. In conclusion Mr. Mott said that in his judgment 'the evolution of the organic world and the puzzling problems of social life were much more rationally explained by this philosophy than by the laws of natural selection and political economy as now understood.'

[11] The Rev. William Higgins Coleman was a master in Christ's Hospital School at Hertford; he was part author of a book on the Flora of Hertfordshire. In 1847 he came to the Grammar School of Ashby-de-la-Zouch. He contributed notes upon mosses and flowering plants to the Flora of the district surrounding Tutbury and Burton-on-Trent, by Edwin Brown in Sir Oswald Mozley's *Natural History of Tutbury*, 1863. The writer of the article on him in the *Dictionary of National Biography* does not seem to have known of his manuscript Flora of Leicestershire.

[12] The Rev. Andrew Bloxam is also in the *D.N.B.* It is there said of him; 'He may be regarded as perhaps the last of the all-round British naturalists.'

Further, that, as an elevating and moralising influence upon mankind, some such view of the universe as that suggested by this philosophy would be the next great influence brought to bear upon society in the next era of mental struggle and reform (*Transactions of Leicester Literary and Philosophical Society*, vol. iv. (1895–98), pp. 510–513.[13]

Mr. Mott was certainly a man of a very active and self-confident mind which delighted in the details of botanical observation, and in those bold flights or dives by which science soars or plunges into philosophy.

Among those who were thanked by the editors of the Flora was James Francis Hollings. He was a master in the Proprietary School and had taught F. T. Mott. 'He was a deeply learned man and studied science as well as literature.' 'His weekly lectures on science, many of which were open to the public, were, as Mr. Mott says, "an important feature of the curriculum of the school." They were always "illustrated by experiments, specimens or diagrams. His varied and accurate knowledge was surprising. Chemistry, geology, botany, or physics—he seemed to be familiar with almost every branch and was always able to make his subjects interesting. . . . Many of his pupils have kept up their interest in science and owe to him their initiation into this delightful study." '[14]

But though he taught science not only to schoolboys but to adults in lectures and papers at the meetings of the Literary and Philosophical Society and at the Mechanics' Institute, his chief studies were in literature and history, of which he had a very wide knowledge, together with the ability of dealing with a particular subject, as in his *History of Leicester during the Great Civil War*. He was thrice President of the Literary and Philosophical Society and Mayor of Leicester in 1859. He died in 1862.

The Rev. Thomas Arthur Preston, Rector of Thurcaston (1885–1905), was an excellent member of the Botanical Section of the Society. In December 1901 he read a paper in which he sketched a plan for a second edition of the Flora and enumerated seventeen points for immediate consideration. It is hoped (April 1933) that this edition will soon be published. Other papers were Reports on the Herbarium. In 1898 the number of specimens had been calculated to be 5,826. In 1902 he considered that the Herbarium had just been doubled. Two old Herbaria had been acquired, one of them that of Miss Kirby.

At the first meeting in February 1905, after the death of Mr. Preston, the Section placed on record an emphatic minute to express appreciation of his work in all branches of botany and of his kindness in helping members individually.[15]

An interesting botanical theory was introduced in a paper, entitled 'On Lichens,' read by Miss Gertrude Clarke in February 1893. She said

[13] In 1883 he argued that instead of two great divisions of organic life there should be a primary fourfold division into Thallophytes, Protozoa, Cormophytes and Metazoa (*Transactions*, 1882–83, p. 53).

[14] *Leicester Memoirs*, by Charles James Billson.

[15] 'A Reminiscence and an Appreciation,' by Mr. William Bell, was read before Section D, May 20, 1908 (*Transactions*, xii, 211–220).

that it had been first propounded twenty-five years before by Prof. Schwendener, that it had at first been met with contempt and ridicule, and was still disputed. The theory was : ' Each Lichen is not a simple plant at all ; but each is really an establishment of two plants living in intimate union and for their mutual benefit. *Every Lichen is a Fungus and an Alga.*'

In October 1894 she (Mrs. C. D. Nuttall, B.Sc.) read a paper entitled ' Symbiosis.' She emphasised the difference between Symbiosis and Parasitism, and told that for many years Symbiosis was only known to exist in Lichens. But Prof. Marshall Ward, a great botanist, ' of whom England may be proud in these days of the ascendancy of German scientists,' had described two other examples of Symbiosis : *at* the roots of many trees, beeches, willows, poplars, etc., and *in* the roots of leguminous plants.[16]

In 1897 Prof. Marshall Ward lectured to the Society on ' Symbiosis.'

' Mendel's Discoveries in Heredity ' was the title of a paper read on January 8, 1904, by Mr. C. C. Hurst, F.L.S., of Burbage. He added to the paper a list of sixty books and articles bearing on this subject ; fifty-one of these had been published in the years 1900–1904. He read two more papers on ' Mendelism,' and in February 1908, in a lecture on ' Mendel's Law of Heredity and its application to Man,'[17] he told that after, by his own experiments and observations, witnessing Mendelian phenomena in peas, poppies, sweet-peas, antirrhinums, primulas, tomatoes, orchids, and other plants, as well as in poultry, rabbits and horses, he had, with the willing co-operation of the inhabitants of Burbage, compiled tables showing the working of Mendel's law in the inheritance or non-inheritance of eye-colour, hair-colour, and musical sense.

An important paper on ' The Cryptogamic Flora of Leicestershire,' by Mr. A. R. Horwood, was read in March 1907. It is somewhat amplified in the *Transactions*, vol. xiii, pp. 15–87.

Steady work was carried on by the Botanical Section till the outbreak of the war. During the war the work was hampered, but not suspended. The report of the Section to the Council in vol. xx of the *Transactions*, a volume covering the years 1915 to 1919, stated that meetings had been held fairly regularly during the winter months throughout the war, but the attendance had not been good. Owing to train difficulties the summer excursions had been very few, but there had been some footpath walks and some visits to gardens. The report of the Flora Committee recorded with regret the deaths of its members, Dr. Finch, Mr. Pattison and Mr. Cooper, and also of Lieutenant G. E. Mercer, who was killed in action. His paper on the Flora of Belgrave and Birstall had been published in the last volume of the *Transactions*. Mr. A. E. Wade, whose paper on the Flora of Aylestone and Narborough was in the present volume, had returned from active service with an injured arm ; despite this he was, as he had been before, giving valuable aid in getting the Herbarium into good order. The work of the Committee had been

[16] There were other papers by Mrs. Nuttall, and she gave a lecture on Trees to the Society in October 1910 (*Transactions*, xv, 26–45).

[17] *Transactions*, xii, 35–48.

much hampered by the absence on active service of Mr. A. R. Horwood, the general editor of the Flora.

Two papers by Mr. G. J. V. Bemrose, an officer in the Museum, were printed in the *Transactions* of the Society: one on 'The Adventitive Flora of Leicester and District' and one on 'The Flora of Rutland.'[18]

Mr. Bemrose was appointed Curator of the Museums and the Art Gallery of Stoke-on-Trent in 1930.

Two notable additions were made to the Herbarium about this time. Mr. Horwood's collection of Leicestershire plants was purchased by Mr. Turner and presented to the County Herbarium. A very unexpected donation was received from the National Museum of Wales—specimens collected by the Rev. W. H. Coleman and Miss Kidger of Ashby-de-la-Zouch.

Geology and Botany are two scientific subjects which have been most continuously and successfully treated by sections of the Literary and Philosophical Society. Other scientific sections have done good work, but only one has rivalled them in years of working. The work of no other has had such results as the sequence of treatises on Geology or the Flora of Leicestershire.

There has nearly always since 1849 been a section for the study of animal life, but its name has often changed: so has its relation to kindred studies. Zoology and Botany have been separate sections; they have been simply joined as 'Zoology and Botany'; joined as 'Natural History'; joined as 'Biology (Zoology and Botany)'; and then very soon a new Section, 'Zoology,' was started which was separate from 'Biology (Zoology and Botany).' The chief object of the new Section was to study the Fauna of Leicestershire. From 1894 to 1915 there was a separate section for Entomology.

To give a just appreciation of the work done by the students of the various branches of Biology is not within the capacity of the compiler of these pages, and it seems to him that the generally abbreviated records of their papers on very various subjects hardly give sufficient material for such an appreciation. But something should be said about the duplication of the Section for Biology, and the working of the new Section.

At the first meeting of the new Section its Secretary, Mr. Montagu Browne, F.Z.S., urged that it should have some definite scheme of work and suggested that the MSS. notes of the late James Harley, 'our Leicestershire Gilbert White,' should be arranged and edited for publication. In the report of the Section 1883–84 it is stated that the published lists of Potter, Babington and Macaulay, and unpublished lists of Harley, Davenport, Ellis, Widdowson, Ingram, Walker and others, have been carefully gone through, and are now being edited by the Secretary. In the report 1884–85 it is stated that the publication of 'The Vertebrate Animals of Leicestershire,' by the Secretary, Montagu Browne, F.Z.S., had begun in the *Zoologist*. In 1889 Mr. Montagu Browne published *The Vertebrate Animals of Leicestershire and Rutland*. In the preface he said

[18] *Transactions*, xxviii, 45–72, and xxix, 21–25.

that he was in possession of the whole of the MSS. of the late James Harley.[19]

While Mr. Harley's notes were in the hands of Section E,[20] Mr. F. T. Mott put before Section D, the other biological Section which studied Botany and Zoology, the MS. of Mr. John Plant's *Catalogue of Leicestershire Mollusca*, with the author's comments and with his own. Mr. Plant's catalogue gave eighty-two species. It was completed in 1850. It referred to two lists, one by the poet, the Rev. George Crabbe, of shells found near Belvoir,[21] and one of shells found near Congerstone by the Rev. A. Bloxam.[22] Six persons are named as finding certain Mollusca, among them 'my friend, Mr. James Harley.' Three manuals of Conchology[23] and Pennant's *British Zoology* are referred to.

The references to, or rather the indications of, old-time students of science, in the preceding paragraphs seem to be pertinent to the purpose of these pages, which is to give an account in an historical sketch of the study of science in Leicestershire. These men gave their minds to their studies without having the encouraging suggestion or the assistance afforded by an already existing Society. Because there were such men it was possible for a Society such as the Leicester Literary and Philosophical Society to be founded and to be strengthened and increased by the formation of its 'Sections' for the study of particular branches of science.

The original scientific Sections for Geology, Botany and Zoology were founded in 1849. In 1850–51 two were added: one for Meteorology, and one for Chemistry and General Physics. These were less permanent.[24] The Section for Meteorology became Meteorology and General Physics in 1871, but it ended in 1882. Chemistry and General Physics went under that name or as 'Chemistry' till 1870. Then it vanished, but reappeared in 1883 in a new Section for Astronomy, Physics and Chemistry.

The Meteorological Section began its work in 1850, the year in which the Royal Meteorological Society was founded in London by Mr. Glaisher. He selected the instruments, which at first were only barometer, thermometer and rain gauge. They were kept at the Museum. In 1873–74 the Rev. A. Mackennal was chairman of this Section. On his advice the Museum Committee of the Town Council purchased a complete set

[19] James Harley was a notable man, much thought of by those who knew him. He lectured to the Society four times in 1844–1858. His lecture on his friend and correspondent, the great ornithologist, the late Prof. Macgillivray, was published in the Society's volume of selected lectures, 1855. The death of the well-known naturalist, Mr. James Harley, was spoken of in the Annual Meeting, 1861. 'J. Harley' was an active member of the Society (see lists of officers) between 1844 and 1853. In a list of dates of arrival of summer birds in Leicestershire Mr. Montagu Browne states that the dates between 1843–55 are from Harley's MSS. (*Transactions*, i (1889), Part i, 27).

[20] No date is given. The text is in vol. i, Part ii, of the *Transactions*, 1887.

[21] Nichols, vol. i, p. cxci.

[22] This is in the *Analyst*.

[23] In the *Shorter Oxford Dictionary* the first known use of the word 'Conchology' is 1776, of 'Mollusk' and 'Mollusca' 1783.

[24] A Section for Chemistry began again in 1924–25, and a Section for Physics in 1926–27.

of meteorological instruments. The Museum was made a Government station. Observations were made and reported and tabulated, the work being at first shared between members of the Section and the Curator of the Museum. As time passed the Meteorological Station became a department of the Museum. In the Museum Report for 1890 the following paragraph occurs: 'The death of the Meteorological Assistant (Mr. J. C. Smith), in 1888, led the Committee to consider if the expenditure of some £70 per annum in keeping up a station of the second class —so near to Loughborough, a station of the first class—was warranted by results. The Committee fully considered the matter in all its bearings, and unanimously decided to discontinue the observations.'

There is nothing in the printed records of the Society about the meetings of, or the subjects discussed by, the Section for Chemistry and General Physics between 1850 and 1870.

In 1883 the Section was reconstituted for Astronomy, Physics and Chemistry. The Rev. Edward Atkins, B.Sc., was the chairman, and Mr. W. S. Franks, F.R.A.S., was the Secretary, till the Section again ceased in 1886–87. Summaries of several of the papers read are in the *Transactions*. They are on abstruse questions in the three branches of science for which the Section had been re-established. There were not many members, and on some dates for which meetings had been announced no meetings were held. The report of the chairman to the Council of the Society in 1887 was a statement of the reasons why the Section resigned its existence. He said that the absence of any kind of apparatus was an almost insuperable barrier to the investigation of physical problems. There would not be enough students to justify the purchase of sufficient apparatus to meet even the elementary requirements of a Section whose title embraced the whole range of physical science from Astronomy down to Chemistry. Experimental researches in even one branch like Chemistry would need a properly equipped laboratory. The members of a Section which embraced as its basis so many sciences could not enter into each other's work. The report ended with a recommendation that the Section should be omitted from the list of Sections for the coming year, for which no officers had been elected.[25]

A Section for Entomology was appointed by the Society in January 1894. It 'made a vigorous beginning.' It had a vigorous separate life for about twenty years. In 1919-20 it was amalgamated with the Section for Biology. When it was founded there were some keen students of Entomology who wished for a section of their own. Some practical work was done by a committee of this Section, which studied and gave advice about injurious insects in farms, gardens and orchards.

After a paper by Mr. Frank Bouskell on October 28, 1896, on 'The Disappearance of Certain Species of Insects, with notes on their Slaughter and Protection,' it was decided to urge upon the Entomological Society

[25] The Rev. Edward Atkins was a master in the Wyggeston Boys' School. The latter meetings of the Section were held in the new laboratory of the school. It seems that it was the first laboratory in Leicester. In 1883 the Society had contributed £100 towards its erection.

of London and on local societies the danger of the extermination of species of rare insects by 'over-collecting,' not so much by collectors who were 'simply foolish' as by those who collected for dealers. The London Society appointed a Protection Committee. The Societies of Northampton, Birmingham, Glasgow, and Marlborough concurred. Lists of insects of which the captures should be limited or inhibited were circulated.

An interesting paper on 'The Scientific Aspect of Entomology'[26] was read before this Section in January 1898 by J. W. Tutt, F.E.S., in which he enlarged on the great change in the science which had come about since the publication of Darwin's *Origin of Species* (1859). 'The "how" and "why" of the things rather than the things themselves became the main consideration of the student, and the sleepy, dry-as-dust science, represented by the herbaria and the cabinets, had breathed into it the breath of movement, of life, of intellectual possibilities hitherto never conceived by its votaries.'

Mr. Frederick Bates,[27] a brother of 'Bates of the Amazon,' was a member of this Section. He made a collection of Coleoptera, which after his death was purchased by the British Museum. In 1907 Mr. Herbert Ellis, who had been chosen to be President for that year because he was considered by all to be the best person to represent the Society during the visit of the British Association, gave a really remarkable presidential address on social questions, and suggested that there should be a Section for Economics. The Section was formed. It has not flagged since its formation.

In the year 1915 a Section for Astronomy was formed. Its first meeting was on June 23, 1915. Before Armistice Day there had been twenty-one meetings, including one open-air study of the sky. This Section was the result of two courses of University Extension lectures. Its last meeting was on April 8, 1925. During its short life it owed much to Mr. J. W. Durrad, F.R.A.S.,[28] and to Dr. J. E. M. Finch.

It is hoped that what has been written so far will give the reader an intelligible sketch of the study of science in Leicestershire, and of its development in Leicester into the co-operative studies of the 'Sections' of the Literary and Philosophical Society. The sketch is, of course, not a complete view: it represents the chief stream of such studies.

In this as in other matters the war was a great break. Post-war is other than pre-war. It has been indicated above that the Sections for Botany, Astronomy, and Economics did not cease their activities during the war. Another piece of work which had begun before the war was not suspended. In 1913 Mr. C. J. Bond, F.R.C.S., Mr. E. E. Lowe, the Curator of the Museum, and the Rev. J. Wallace Watts, Chairman, Vice-Chairman, and Hon. Secretary of the Section for Biology, with the approval and the help of the Museum and Art Gallery Committee, gave lectures with practical work on Zoology. These classes were con-

[26] The paper is in vol. iv, pp. 527–539, of the *Transactions*.

[27] A paper on the Coleoptera of Bradgate Park by him, with a list of 507 species, is in the same volume, pp. 170–176.

[28] Mr. Durrad designed the table of the sun-dial in Museum Square.

tinued, though not without difficulty and not throughout by the same lecturers, all through the war time.[29]

The Report of the Council of the Society for the session 1922–23 contained this sentence: ‘ It may now be said that the depression and difficulties due to the war have passed.’

With regard to the work of the Sections for Geology, Botany, Biology, Economics, and of two new [30] Sections, one for Chemistry and one for Physics, it may after ten years be said that that sentence was not too optimistic.

No attempt is here made to give particular accounts of the post-war work of these Sections, but something may be said of changes in or affecting them all.

The different Sections seem to help one another more than in former years, not only by such a permanent partnership as that between the Sections for Zoology and Botany, but by arranging joint meetings to discuss overlapping subjects. Meetings also are arranged with technical or academical bodies, and visits are paid to places where work is carried on under the guidance of applied science.

The Museum was the child of the Literary and Philosophical Society. After a period in which it may be said to have been first a nursling and then a pupil of the Society, it acquired independence not only from parental authority but from all parental interference. In the many years since this emancipation was completed there has been harmony between parent and child. The Museum as an institution and its curators and other officers—not a few of them have held office in the Society and its Sections—have been leaders in scientific studies in Leicester. Till late in the nineteenth century this could be said of no other institution. In modern days the growth and development of the University College, of the Colleges of Art and Technology, and of the Scientific Departments of Secondary Schools, have made a great change. There are in Leicester a number of men and women who are in virtue of their profession students and teachers of science. There has also been an increase of the number of experts in applied science who are employed in the service of the city, or are engaged in industry. The conditions of local scientific study have changed, and its possibilities are greater than ever. It may reasonably be hoped that there will always be a number of people who, though not professionally engaged in science, will find in some of its provinces an attractive but serious parergon for their leisure time, and that those who are professionally learned in one province may be amateurs in others. So it is reasonable to hope that such little societies as the Sections of the ‘ Lit. and Phil.’ may in the future surpass the good work of their bygone years.

Such a hope was expressed long ago in the Report of the Council to the Annual Meeting in June 1877: ‘ There is no reason why the Sections should not become small Societies in themselves, of recognised position,

[29] Three out of four first-year medical students who were attending these classes were killed in the war.

[30] The Section for Chemistry began work in 1924–25, that for Physics in 1925–1926.

able to hold their own by the side of other large Societies in the kingdom; why in fact there should not be a Geological, a Natural History, or other Society, affiliated to the old Parent Society, but each working in its own sphere.'

In his Presidential Address in 1912 Dr. Astley V. Clarke spoke of the Sections as the *raison d'être* of the Society.

Times have changed since 1877, and since 1912. It is still much to be wished that such small societies may continue to work each in its own sphere, but each ready to work together with others, so that there may be, in effect, a Leicester Association for the Study of Science.

The writer is aware that the foregoing is an incomplete account of the study of science in Leicester. It gives no account of institutions which have among their work in other subjects given instruction in science—such as the Mechanics' Institutes from 1834 to about 1860, Working Men's College (now Vaughan College), Adult Schools, University Extension Lectures, and other bodies—but it is hoped that it gives a correct account of the most permanent and important streams of science study other than that in modern colleges and modernised schools.

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